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WATER SUPPLY AND USE
IN THE TENNESSEE VALLEY

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PREFACE

The Tennessee River Valley is situated in a region of generally ample rainfall and water supplies. Five of the Valley states rank among the country's ten wettest. The driest areas within the Tennessee Valley boundaries receive more rainfall in an average year than half the states of the United States. The average annual rainfall in its wettest areas is second only to that which falls in the mountains of the Pacific Northwest.

Historically, the public interest in water resource policy in the Tennessee Valley was, until 1950, largely centered on the development of navigation, the control of surplus water, the reduction of pollution, and the use of the streams and lakes for recreation and wildlife propagation. Although a few localities had experienced water shortages in dry summers, there are no indications that the people of the Valley were generally aware of any need for legislative changes to control water uses.

Beginning in 1950, a growing awareness developed throughout the humid East, including the Tennessee Valley, that increases in population, higher standards of living, and rapid industrial growth were pushing the demand for water upward. In 1951 the Valley experienced the first of a series of five dry years. This concurrency of expanding use and drought decreased the margin between demand for water and supply sufficiently to arouse a consciousness of competitions that had not existed before.

Irrigation, one of the most difficult uses to reconcile with other uses, began in these dry years to spread rapidly over the Valley. Little was known about the magnitude of the irrigation use, or how rapidly this use might increase in the future. Some predicted that every acre of cropland near water would some day be irrigated. Municipalities and industries were disturbed that streams would dry up if farmer after farmer pumped water onto his crops. The farmers began to think about some method of water allocation to protect investment in irrigation equipment and dams. Pressures built up, and state legislatures were urged to take action quickly to protect their states' water resources.

TVA has a natural interest in the basic problem for several reasons. One of these results from its statutory responsibility for operation of the unified system of Tennessee River dams and reservoirs. Another stems from its responsibility for conducting studies of potential value to both the Federal Government and the seven Valley states in promoting the proper use, conservation, and development of the natural resources of the Tennessee River drainage basin and adjoining territory related to the Tennessee River development. In addition, TVA over a 25-year period has accumulated a large amount of water resource data which could be useful to both the TVA and others in connection with studies of the area's water problems.

With the dual objectives of providing a basis (a) for future water use considerations by TVA in its operating programs, and (b) for cooperation with the Valley states in the solution of future water problems, TVA initiated in 1957 a study of the water resource and use situation in the Valley. The study was planned to include: (1) an examination of the economy of the Valley and the trends for the foreseeable future as they may affect water uses; (2) an analysis of the magnitude, distribution, and quality of the water resource, the physical factors that affect its distribution, and ways in which the resource might be extended; (3) an estimation of the present water use; (4) a prediction of the water use in 1975 and the conflicts that may develop; (5) an exploration of opportunities for future action in water resource development, and (6) an examination of present and possible future water use legislation.

This study has been carried out by an Advisory Committee appointed by the General Manager to represent the various competences necessary for such a study. The Committee is as follows:

WATER USE STUDY COMMITTEE

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Acknowledgments

During the course of this study, members of the Committee visited state officials interested in water resources in Alabama, Kentucky, North Carolina, and Tennessee to discuss the project and to learn how the study could be made most useful to the states. Valuable information and suggestions were obtained during these discussions from the following:

Alabama:

Pleas Looney, Director, State Planning and Industrial Development Board

Kentucky:

Laban P. Jackson, Commissioner, State Department of Conservation

Robert L. Bolin, Director, Division of Flood Control and Water Usage, and Chairman, Water Resources Study Commission

North Carolina:

Gen. J. R. Townsend, Chairman, State Board of Water Commissioners

W. H. Riley, Executive Secretary of the Board

Tennessee:

Harold V. Miller, Executive Director, State Planning Commission

Linzy D. Albert, Acting Director, State Planning Commission

Raleigh W. Robinson, Water Engineer, Division of Water Resources

Much useful data on water use and waste disposal by municipalities and industries were obtained from the following public health officials in the Valley states: In Alabama, A. N. Beck, Chief Engineer and Director, Bureau of Sanitation; in North Carolina, J. M. Jarrett, Director, Division of Sanitary Engineering, and E. C. Hubbard, Director, Division of Water Pollution Control; in Tennessee, Julian R. Fleming, Director, Division of Sanitary Engineering, and S. Leary Jones, Director, Stream Pollution Control; and in Virginia, E. C. Meredith, Director, Division of Engineering in the State Department of Health, and A. H. Paessler, Executive Secretary, State Water Control Board.

Erdman B. Debler, Consulting Engineer, of Denver, Colorado, advised the Committee in the field of irrigation and other agricultural water uses.

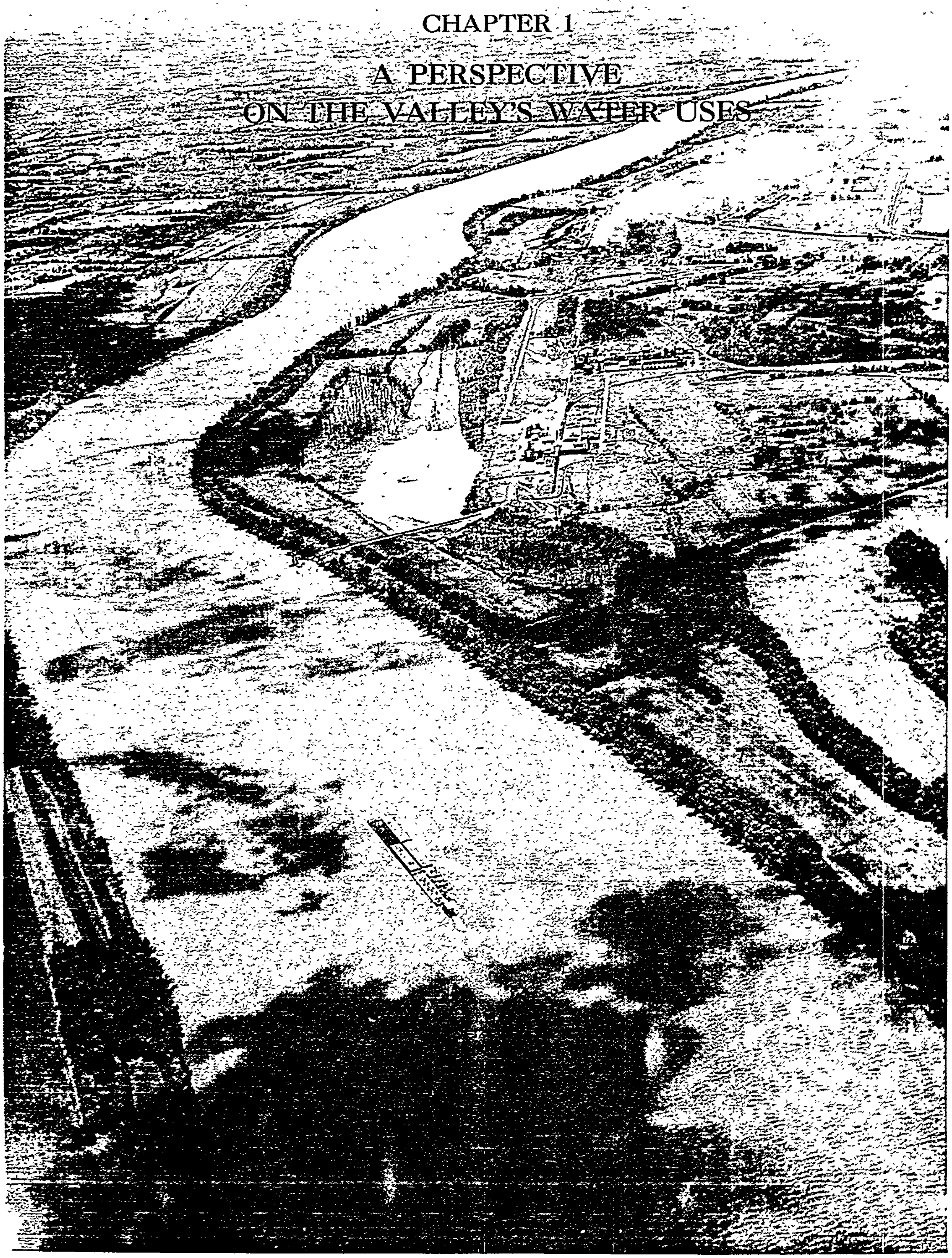
To obtain first-hand information on the administration of the permit type of water use legislation, the Committee conferred in Baltimore, Maryland, with Dr. J. T. Singewald, Jr., Director, Maryland Department of Geology, Mines, and Water Resources, and in Des Moines, Iowa, with Othie R. McMurry, Director, Richard L. Rick, Deputy Water Commissioner, and Merwin D. Dougal, Engineer, of the Iowa Natural Resources Council.

The Committee makes special acknowledgment for data to the Ground Water and Surface Water Branch offices of the U. S. Geological Survey in the Valley states, to the U. S. Weather Bureau, to the U. S. Department of Agriculture, and to the several state agricultural experiment stations.

Within the TVA organization, valuable contributions and suggestions were made by many individuals. Among these were the following: in the Division of Agricultural Relations - E. L. Baum, Chief of the Agricultural Economics Branch, Jack Knetsch, Agricultural Economist, and Lester Odum, Soils Specialist; in the Division of Forestry Relations - Lawrence F. Miller, Chief of the Fish and Game Branch, and Erwin G. Wiesehuegel, Chief of the Forestry Investigations Branch; in the Government Relations and Economics Staff - Hershal L. Macon, Economist; in the Division of Health and Safety - Milo A. Churchill, Chief of the Stream Pollution Control Section, and Harold L. Elmore, Public Health Engineer; in the Division of Law - Harriet D. Holt, Attorney; in the Division of Navigation and Local Flood Relations - Clifton T. Barker of the Division Staff; and in the Division of Water Control Planning - Albert S. Fry, Chief of the Hydraulic Data Branch, Don H. Mattern, Chief of the Project Planning Branch, B. C. Moneymaker, Chief of the Geologic Branch, Edward J. Rutter, Chief of the Flood Control Branch, and members of the staffs of each branch.

CHAPTER 1

A PERSPECTIVE ON THE VALLEY'S WATER USES



CHAPTER 1

A PERSPECTIVE ON THE VALLEY'S WATER USES

A great deal has been published in recent years about the tremendous amounts of water now being used in the United States and the rapid rate at which the uses are growing. Predictions have been made that, between 1950 and 1975, municipal uses in the United States will increase one and one-half times, manufacturing uses will more than double, and that use for steam-electric power generation will amost triple in the same 25-year period. These predictions have caused considerable concern among water users and those responsible for the conservation of the water resource.

Some of this concern regarding the water situation results in part from a natural tendency to sum up the volumes of water required for each use before comparing the total with the available supply. This addition of uses fails to give consideration to the repeated use that is made of the same water. Like a photograph taken too close to the subject, the water use looms much too large in proportion to the blurred background of the water resource.

If, for example, the 1975 withdrawal needs in the Valley were added together, they would total about 23,000,000 acre-feet of water. In the record dry year of 1941, the discharge of the Tennessee River at its mouth was only 22,500,000 acre-feet. Apparently, here is a critical situation even neglecting the millions of acre-feet of water also being used for hydroelectric power, recreation, navigation, waste dilution and the other in place and regulatory uses. Actually, these totals, which are the figures often viewed with concern, are significant as a measure of the utilization of water but have little meaning as a measure of the depletion of the resource with respect to other uses. A large part of the withdrawal use is actually only a local diversion and has no perceptible effect on the availability of water for other uses. For example, steam-electric plants need very large amounts of water but if all the steam plants in the Valley were shut down, municipalities or industries would have no more or no less water than they had before. The only effect would be that for a few miles below each steam plant site the water would be a little cooler.

Water Supply

Hydrologically the Tennessee River Basin, an area of 40,910 square miles, is situated in one of the most humid areas in the United States. Annual rainfall averages 52 inches and ranges from as much as 92 inches in the mountains to as little as 39 inches in the shielded valleys. While average growing season rainfall is ample for crops, droughts resulting from poor distribution occur with surprising frequency. Annual runoff ranges from 53 inches to 10 inches in the same areas and averages 22 inches over the entire Basin. Surface water is the major source of water supply. Water from wells is generally an uncertain source and in most areas wells yield only enough to satisfy domestic and small municipal uses. Mineral quality of unpolluted waters varies considerably, with the most desirable water being located in the streams of the Appalachian Mountain region.

High streamflow occurs generally in the months December through April while lowest flow is experienced in September and October. Many small to moderate-sized streams in the central and western parts of the Valley go completely dry in the fall of drought years. Although average annual discharges of the Valley streams seem to provide ample water for most uses, a good proportion of this flow occurs in the winter months when it cannot be utilized fully. Only through reservoir storage can this surplus water be made useful in the summer and fall months of heavy demand. The TVA system of reservoirs provides substantial amounts of such storage on the main stream of the Tennessee River and most of its major tributaries.

The TVA Reservoir System--TVA was created by Act of Congress in 1933 "to improve navigation in the Tennessee River and to control the destructive floodwaters in the Tennessee River and Mississippi River Basins." The over-all directive included development of the power potential of the region, thus placing the responsibility for the multiple-purpose development of the water resources in one agency. Under this directive, TVA has completed projects along the main Tennessee River which provide a 650-mile navigation channel from the mouth of the river at Paducah to Knoxville. These projects include storage reservations for flood control and power installations for the generation of hydroelectric power. Large storage reservoirs have been constructed on the major tributary streams above Chattanooga. These tributary reservoirs provide the major flood control protection and, in addition, regulate flows for power and sustain releases for navigation during periods of low flow.

The seasonal operating plan followed to accomplish the statutory purposes involves storing part of the excess streamflow during the wet winter and spring months and supplementing streamflow during the dry months of summer anf fall by the release of this water from storage. These reservoir operations result in seasonal variations in water levels ranging from a few feet in the mainriver lakes to as much as 185 feet in the tributary lakes. Reservoirs are drawn to their lowest levels for flood control on January 1. Gradual filling is permitted through March as the probability of a succession of large floods decreases. If a flood occurs, water is stored in the reservoirs temporarily during the period of the flood crest. It is released as soon as practical to return the reservoirs to flood reservation levels in case a second flood should occur. Beginning in April, the reservoirs are allowed to fill as rapidly as streamflow permits. During the summer and fall, this stored water is then released through the turbines to generate hydroelectric power, to aid in maintaining flows on the lower Ohio-Mississippi Rivers for navigation, and to lower the reservoirs to the planned flood control levels by the next flood season. Mainstream reservoir levels provide for at least 9-foot draft navigation throughout the year. Reservoir water-level management aids in the control of the malaria hazard. Secondary but substantial beneficial effects from regulation accrue to recreation, water supply, and stream sanitation.

In the execution of this program, TVA cooperates with local, regional, and national agencies, both public and private, which perform functions relating to national defense, weather forecasting, streamflow measurement, navigation, flood control, electric power, public health, land conservation, fish and wildlife, recreation, and other public interests affected by water level and stream regulation.

The continuous chain of Tennessee River lakes stretching for 650 miles from the Ohio River to Knoxville represents a priceless source of water for many uses in the Valley. This water is accessible at numerous points along a shoreline of 7,000 miles and over a surface area of 450,000 acres. If the tributary lakes are included, the shoreline totals over 10,000 miles and the surface area some 600,000 acres.

Effect on Economic Development--The water supply situation as well as the topography have considerably influenced the economic development of the Valley area. The larger cities and much of the industry in the Valley have been located in between the mountain areas from Bristol southwestward to Chattanooga and along the main stem of the Tennessee River westward from Chattanooga to the mouth at Paducah. Exceptions are the city of Asheville and some of the paper and synthetic fiber plants which have established in the Appalachian Mountain area to obtain water of high quality. Principal railroad lines serving the Valley follow up the stem of the main river and northeastward along the Holston River. Large and assured supplies of water are available in this area from the chain of TVA reservoirs. Flood control on the river and its major tributaries provides protection to communities, industrial sites, and farm lands. River navigation provides low-cost transportation of heavy commodities as far as Knoxville. All of these factors favor the growth of metropolitan areas and industrial complexes in this intermountain region of the Valley. Except for minor areas, much of the rest of the Valley has been devoted to forestry and agriculture.

During the past 25 years and especially since World War II the whole Valley has been experiencing the effects of a steady change from a largely agricultural economy to one characterized by urbanization and industrial growth. The fastest growth in population has occurred in the Valley counties that include the larger cities. Per capita income, although still below the national average, has been increasing faster than the national rate since 1940, largely as a result of this belated shift to a non-farm, industrial economy. The outstanding industrial growth in recent years has been in the high wage, large water-using industries. These changes, which have resulted in a generally higher standard of living and an accompanying greater use of water, are expected to continue in the same direction in the foreseeable future.

Water Use

Classification of Uses--For the purposes of this study, the water uses of the Valley have been grouped into three classes depending upon the manipulation of the water required for the use. First are the in place uses which involve no withdrawal or direct regulation. Included are uses for recreation, navigation, fish and wildlife, pollution dilution, and drainage. The second group includes the regulatory uses, such as flood control, lockages for navigation, mosquito control, and hydroelectric power.

Both the in place and regulatory uses require quantities of water which are very large but which in some cases cannot be determined. Except for pollution dilution, these two classes of uses involve little or no consumption or deterioration of the water.

The third class of use is the group of withdrawal uses. Included are irrigation, rural (household and livestock), municipal, industrial, steam-electric power generation, and mining operations. Consumption of water by these uses varies from practically zero for steam-electric plant use to nearly 100 percent for sprinkler irrigation. Deterioration of the water ranges from negligible to serious. This class of use is the source of more conflicts than either of the other two classes.

Consumptive Uses--The withdrawal uses, other than that for steam-electric generation, involve some degree of consumption of the water. Consumptive use is defined as the quantity of water discharged to the atmosphere or incorporated in the products of the process in connection with vegetative growth, food processing, or incidental to an industrial process.[1]

Average rates of consumption used in this study were as follows: irrigation - 90 percent, rural domestic - 50 percent at present and 40 percent in 1975 when the number of piped homes will be much larger, municipal - 10 percent, industrial - 5 percent, steam-electric power generation - negligible, and mining operations - 25 percent.

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1. Definition by American Water Works Association Task Group, 1953.

Volume of Withdrawal Use--The following tabulations summarize the present and predicted 1975 withdrawal requirements and the estimated amount of water that would be consumed by each use. The total requirement for water shown in the tabulations does not take into account the substantial overlapping of use of the same water by the six withdrawal uses.

ANNUAL WITHDRAWAL AND CONSUMPTIVE USES

	Total Withdrawal Acre-Feet		Consumptive Use Acre-Feet	
Use	Present	1975	Present	1975
Irrigation	20,000	80,000	18,000	72,000
Rural	76,000	121,000	38,000	48,000
Municipal	175,000	300,000	17,000	30,000
Industrial	730,000	1,094,000	36,000	55,000
Steam-electric power*	6,000,000	20,900,000	0	0
Mining	44,000	65,000	11,000	16,000
Totals	7,045,000	22,560,000	120,000	221,000

For comparison with the totals in the foregoing table, the annual average and dry-year discharges at the mouth of the Tennessee River are as follows:

Average year	47,500,000 acre-feet
Driest years	
1941	22,500,000 acre-feet
1904	24,000,000 acre-feet
1925	28,700,000 acre-feet

The peak of withdrawal uses in the Valley occurs in the summer months, particularly in the June-September period. The municipal and the rural

*Figures are for condenser water use only. Quantities used for boiler feed, sanitation, dust control, etc., are small. Consumptive uses within the TVA steam-electric plants are a negligible percentage of the total use.

domestic uses are at a maximum in July. The irrigation maximum occurs in July and August. With higher water temperatures it is probable that the use by industry for processing and cooling is greatest in the warmer months. In the following table the estimated volume of water used and consumed in this four-month period is listed for each withdrawal use at present and as predicted for 1975.

JUNE-SEPTEMBER WITHDRAWAL AND CONSUMPTIVE USES

	Total Withdrawal Acre-Feet		Consumptive Use Acre-Feet	
Use	Present	1975	Present	1975
Irrigation	19,500	79,400	17,600	71,500
Rural	29,500	46,000	14,800	18,400
Municipal	60,200	104,000	6,000	10,400
Industrial	259,000	387,000	13,000	19,400
Steam-electric Power*	2,000,000	7,000,000	0	0
Mining	16,000	22,000	4,000	5,400
Totals	2,384,200	7,638,400	55,400	125,100

The June-September streamflow at the mouth of the Tennessee River in a dry and average year is as follows:

Dry year (1925)	2,755,000 acre-feet
Average year	8,597,000 acre-feet

It is apparent from the two tabulations that the direct total of all gross withdrawal uses in 1975 will exceed the water available in the Tennessee River at its mouth in an extreme dry year. It must be noted again that this is only an apparent shortage resulting from the adding up of many overlapping uses of the same water. In particular it will be noted that the estimated cooling water requirements for steam-electric power amount to about 90 percent of the total withdrawal use.

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*See note for previous table.

Local Shortages--When total withdrawal uses and total stream discharges for the annual and June-September periods are examined for some of the major subareas where summer flows are low, there is still no indication of serious widespread shortage problems now or in 1975. However, summer season shortages do exist now on smaller areas and there will be more of these by 1975. An example is Limestone Creek, a north Alabama stream with a 286-square mile drainage area that was pumped dry in 1956 by a group of large cotton irrigators. A problem is impending also on the Duck River at Columbia, Tennessee, where the municipal system and an industrial complex are utilizing practically the entire low flow of the river. The continued unrestricted expansion of irrigation on the 1,200-square mile basin above the city could affect future municipal and industrial development unless an increased water supply is provided. Several dam sites have been identified on the Duck and Elk Rivers where water could be impounded for multiple-purpose use. Undoubtedly good sites will be found for development on other streams when the need for storage arises.

Effect of Consumptive Use--Of the 7 million acre-feet of water now withdrawn annually from streams, lakes, and ground water in the Tennessee Valley, only about 120,000 acre-feet, or less than two percent, is consumed. In 1975 the annual consumptive use will be an estimated 221,000 acre-feet, about one percent of the withdrawn volume. Even in the June-September period the consumptive use is only about two percent of the total water withdrawn.

When the consumptive use figures for the Valley are compared with the total flow at the mouth of the Tennessee River it is apparent that a general shortage of water in the Valley need not be expected for many years. However, this comparison may give a misleading impression as far as local situations throughout the Valley are concerned. Local shortages resulting largely from heavy summer season consumption exist now on small areas and these may be expected to increase in number and frequency.

Effect of Pollution--Another important factor in reducing the amount of water available for use in the Valley is the deterioration in quality of the water as a result of use. Where this is serious the water is of little value except, perhaps, to float boats or turn turbines. In the Tennessee Valley, pollution of streamflow by industrial discharges is extremely damaging in several rivers in the eastern section. Among these are the French Broad River, the Pigeon River, the lower Tuckasegee River, the Emory River, the North Fork Holston River, and the lower portions of the Watauga and South Fork Holston Rivers. This is a traditional use of these rivers, and progress toward abatement in some areas is slow. Most of these streams, if unpolluted, would provide water that would be highly desirable for other industrial use as well as for domestic use and for recreation. At present their flow has little use except for sewage disposal, navigation, and power generation. When these effects of serious pollution are considered, the amount of the total water resource of the Valley taken out of service to other users is somewhat greater than the consumptive use values shown in the tabulations.

All of the Valley states have stream pollution control laws and generally are making good progress in the control of industrial wastes and municipal sewage. Interstate cooperation in reducing pollution will result from a Tennessee River Basin water pollution control compact which was approved by the Congress and the President in August 1958 and which has so far been ratified by Tennessee, Mississippi, and Kentucky.

Planning for the Future--It is important to appreciate that many of the reported water problem situations result not so much from shortages of water supply as from lack of adequate planning for future needs. Shortages during low-flow periods such as that of 1951-1955 often indicate that a municipality or industry has outgrown its supply facility, which should have been planned ahead for just such an emergency. The states could provide a valuable service to their small municipalities by advising or assisting them in this advance planning.

Conflicts Among Uses

Some conflicts among water uses exist in the Valley despite the generally favorable water resource situation. These conflicts may develop when highly consumptive uses compete with other uses for limited supplies of water, when pollution by one use renders the water unfit for other uses, or when reservoir levels or discharges are regulated in such a way as to satisfy one use but not meet fully the needs of another. The extent and significance of the conflicts resulting from these and similar situations are not easily determined.

Consumptive Uses versus Hydro Power--Irrigation and other highly consumptive uses throughout the Valley compete with each other and also with non-consumptive uses such as hydroelectric power generation. For nine or more months each year practically the entire runoff of the Tennessee River Basin is used through the turbines of one or more hydro plants. Any diversion of this runoff reduces power production. At present, only a small portion of the consumptive withdrawals are directly from TVA reservoirs. Predictions of growth in the consumptive uses indicate that there will be substantially greater diversions of water from use for hydroelectric power generation. However, while these consumptive uses, as indicated in the preceding tables, will almost double between now and 1975, the amount of water thereby diverted from the hydro plants will be only one percent of the total water available for power generation in a dry year.

Pollution versus Other Uses--The important conflicts, largely limited to the eastern part of the Valley, that result from the effects of pollution of streams by industry have been mentioned previously. This pollution seriously affects recreation, fish propagation, municipal use, and the industrial growth of the region downstream.

Reservoir Operation versus Fish and Wildlife--There has been no significant conflict in the Valley between the use of water for fish and wildlife propagation and the operation of the TVA reservoirs for navigation, flood control, and power. Actually, fish and wildlife in the Valley have been greatly benefited by the water resource developments of the past 25 years. The fear that reservoir drawdown would be detrimental to fishing has been largely removed by experience and study on the TVA lakes. There is considerable evidence that, under Valley conditions, proper water-level manipulation actually furnishes better fishing than static reservoir levels.

Reservoir Operation versus Recreation--Tremendous potentials for recreation have been created in the Valley by the TVA reservoirs which were authorized, planned, and built for the primary purposes of flood control, navigation, and power generation. A large number of public and private recreation interests have come into existence around the reservoir shorelines to utilize this resource. Some of these interests have registered complaints because of the drawdown necessary on some of the tributary lakes for flood control and power in the late summer and fall. Fortunately, however, the highest and most stable reservoir conditions coincide with the most active part of the recreation season, and the low reservoir levels occur when the recreation use is declining or dormant. Experience to date in the Valley has shown that the tributary reservoirs as a group, despite their deep drawdown, are used more intensively for recreation than the mainriver reservoirs which have much less drawdown.

Economic Relationships Among Uses

A knowledge of the economic relationships among the Valley's water uses would be essential if widespread shortages and serious conflicts developed. Considerable thought was given in this study to a possible evaluation of these relationships. As the study progressed it became obvious that such an evaluation would be an extremely complex job and would require much more data collection and analysis than was feasible in the time available. When over-all investigations showed that the need for this type of information was not urgent in the Valley, the evaluation efforts were discontinued.

This does not mean that an evaluation study should not be carried out in the near future. As more and more demands are placed on the water resource it will be necessary to search for techniques for balancing the economic and social values of one use against others so as to make decisions in the best interests of the public. The traditional alternative in most states has been to rely on the forces of competition for available water resources as a means of assuring the best use. It may well be that no better method will be found to satisfy the needs of some areas in the near future.

Extending the Water Resources

Several measures may be available in the Valley for extending the water resource in areas of local shortage. Among these are increasing the efficiency of use, abatement of pollution, control of water on the land, regulation of flows by impoundment, and perhaps, in time, modification of the weather and use of less desirable water.

Methods of increasing efficiency of use are fairly well known to municipalities, industry, and agriculture. Among these are recirculation of water by industry, metering of municipal and industrial supplies, use of cooling towers and cooling ponds, reducing leakage and other wastes, and improving irrigation techniques. Additional research, especially in the irrigation use, is desirable. Application of these methods can be expected when shortages justify the expenditure necessary.

The present steady progress in the abatement of pollution being accomplished by the state agencies in the Valley will ultimately make wider re-use of the available resource possible. These agencies should be given every encouragement to continue this work through cooperative action by private enterprise, municipalities, the states, and the Federal government.

Much research has been carried out on the control of water on the land. This research, generally carried out on small watersheds, has developed principles of forestry and agricultural management, the application of which result in decreases in erosion and wasteful storm runoff and which, under certain conditions, may improve the low flow of streams. Pilot studies show that the tendency toward improved distribution of runoff brought about by land management is not accompanied by an increase in total yield of water. The most positive results are improvement in water quality and retention of topsoil. The effect of the application of these principles over the Valley during the past 25 years cannot be measured with any degree of accuracy for the entire Valley but there are evidences on smaller areas that significant benefits have occurred.

More Storage Reservoirs--Probably the most direct and reliable way to bring about maximum availability of the water resource is by storage, where construction of dams and reservoirs is economically feasible. Much of the apparent surplus of water in the Valley that is indicated by annual discharge figures is water that could not have been used under natural conditions at the time it flowed down the stream channels.

Numerous cities, industries, and irrigators are now taking advantage of the regulation and storage provided by the TVA reservoirs. Only a relatively small portion of the Valley, however, has direct access to these benefits. The Duck, Elk, and Emory River basins, where low summer flows may cause serious problems, have no presently available storage (except for the Arnold Engineering Development Center's water supply reservoir on the Elk River and numerous farm ponds). It would appear that multiple-purpose reservoirs in these basins and elsewhere in the Valley may in time be the only effective answer to local shortage problems. It is conceivable that these reservoirs might be built with partial state and Federal support. Charges might be established for direct withdrawals and some method developed for allocating costs to those benefited by regulation in the streams below the dams. Perhaps in some cases the power potential could be developed to help pay for costs.

TVA has assembled a great deal of information on the selection of sites, design and construction of dams, and operation of reservoirs that would be of value to state agencies and private interests in the development of small multiple-purpose reservoirs throughout the Valley.

Water Rights

Any examination of water resources and water uses in a region inevitably brings up questions of water rights and the possible need for new water rights legislation. The system of water rights law in six of the seven states of the Valley is based on the doctrine of riparian rights. One state, Mississippi, has shifted over to the doctrine of prior appropriations under a law which went into full effect in the spring of 1958. The riparian rights rule has the advantage of flexibility in permitting changes to new or more socially desirable uses and the disadvantage of a lack of certainty as to the amount of water on which individual users can rely. The prior appropriation rule provides a high degree of certainty, at least to the senior appropriators, but is relatively inflexible and tends to place a freeze on future changes to meet changing economic and social conditions.

Permit Systems--At the present time there is a growing interest among the eastern states in a type of system providing for permits for certain limited periods but not for appropriative rights. Existing uses undertaken under the riparian rights rule are generally preserved. The objective is to provide a degree of security to the user without entirely sacrificing flexibility and adaptability to change. The experience of the few states which have adopted the permit type of legislation is probably not yet sufficient to serve as an adequate guide to others. Under such a system, the composition and powers of the administering agency are extremely important to the successful operation of such legislation. The agency is likely to be subjected to many conflicting pressures as the demand for available water supplies grows. The enforcement of limitations on rights of use may be expensive and difficult to accomplish.

Need for Change--On the basis of the findings of this study, there appears to be no urgent present need for such basic changes of general application in water rights law in the Valley states, at least insofar as the Tennessee River Basin is concerned. The Tennessee Valley states are and will be for some time to come a region of generally surplus water supply, although some local areas will experience shortage problems. For this reason, these states are in a position to study carefully the problems involved in new legislation, to observe and profit by the experiences of other states, and to take advantage of their own experiences in their limited areas of water shortage.

A few legal changes short of the adoption of statewide permit systems may, however, be desirable soon to take care of the present problems. One of these would be the provision in each state for a qualified commission to collect water resource and water use data and to carry on a continuing study of water problems. Most of the Valley states already have at least the framework of such a commission. Some of these groups might be strengthened technically and given adequate budgets and a definite program. They would also serve as continuing bodies to examine emerging water questions and to make constructive efforts to improve both laws and administrative practices.

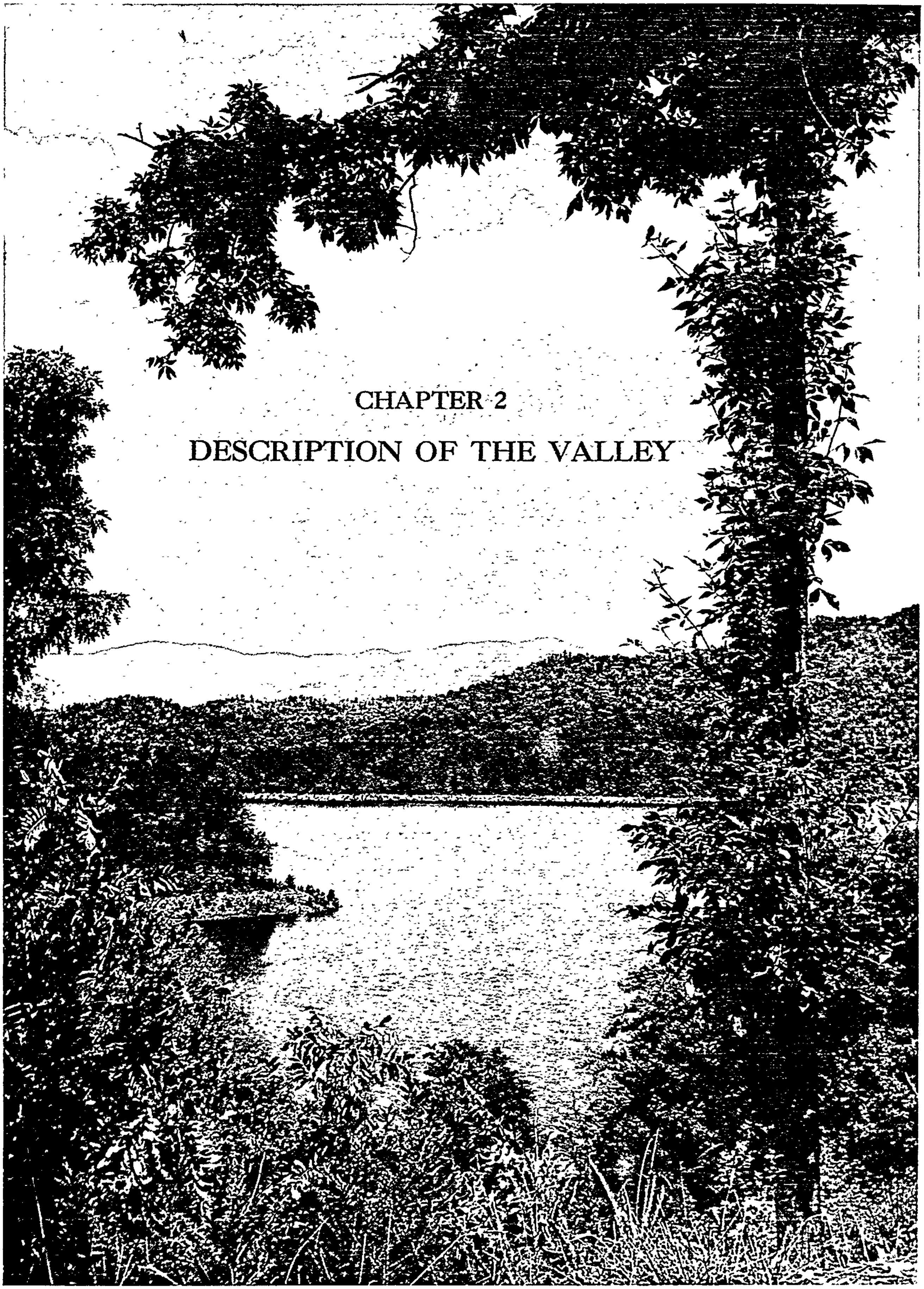
In most of the states, withdrawal of water by a municipality for its citizens and for industries is not an accepted riparian use. Some adjustment or revision of the law may be desirable to give this use riparian status and thereby enable cities to obtain water with less need to resort to the expense of eminent domain proceedings. In return, the municipalities might be required to adhere to certain requirements regarding quantity of returned water, the location of the point of return, treatment of the discharge, and provision of storage to reduce the drain on the water resource during low stream flows. These conditions would seem sufficient ordinarily to protect most other users of the water. Similar conditions might also be applied to the industrial use.

With regard to irrigation use, some legislation may be necessary to control the use of water by irrigators in order to protect other essential uses, including that by other irrigators. The control measures should be applicable on a local basis only in areas where, in the opinion of the state water resource commission, shortages exist or are imminent. Irrigators in these local areas might be required to provide impoundments, either individually or by district action, which would have to be filled by surplus flows prior to May 1 or June 1. The design, construction, and operation of such impoundments would be subject to approval by the state agency to insure safety and maintenance of releases into the streams during the summer season.

Administration--Regardless of what type of new water rights legislation may be adopted in any state, problems of administration will grow and become sharpened as the demands on the water resources increase. One problem will be that of establishing an administrative body on a basis that will assure adequate and balanced consideration of various water uses with full recognition of state-wide variations in water resources as related to the economic demands. This suggests that some type of decentralized administration on a regional "grass roots" basis within state boundaries could have substantial merit. In some states there are natural subdivisions which would have distinctive characteristics as to both water supply and possible future uses. For example, the state of Tennessee could logically be subdivided into four distinct regions comprising (1) the Tennessee Valley upstream from Chattanooga; (2) the Tennessee Valley downstream from Chattanooga; (3) the Cumberland River Basin, and (4) the Mississippi River drainage area in west Tennessee. Each of these four regions has special characteristics with respect to water supply, the extent and nature of existing water resources development and the opportunities for future development, the topographic characteristics, and the potential for various water uses. Under these circumstances it might be practicable for water rights administration to be conducted by representative bodies within each area operating under the over-all control of and within policies established by a small state-wide administrative body. The state body might consist of a representative from each regional group, together with an "at-large" member. Such a system would appear to offer distinct advantages toward assuring that the desires and needs of each region of the state would be met, so far as possible, with the least amount of state-wide conflict.

Opportunities for State Action

While the Tennessee Valley is now blessed with plenty of water, its needs will have to be continuously examined by the Valley states cooperatively with Federal and private agencies to the end that there will be no arrestment of growth in any part of the economy as a result of water shortage. Planning and administration should be kept flexible enough to take care of changes as they occur, to meet problems as they arise, and to provide full utilization and protection of the water resources of the Valley. A later chapter of this report suggest some directions that planning by the states might take.


CHAPTER 2
DESCRIPTION OF THE VALLEY

CHAPTER 2

DESCRIPTION OF THE VALLEY

The Tennessee Valley is a region of forests, open grasslands, small farms, and man-made lakes. Of the Valley's 26,160,000 acres, 14 million acres are in forest, 11-1/2 million acres are open lands, and nearly 700,000 acres are covered by water. To the economist, geologist, forester, agriculturist, and hydrologist, alike, the Valley is replete with contrasts. Among other factors these contrasts result from the rugged mountain versus broad valley topography of the area, from the Valley's location touching the Deep South on one side and the Midwest on the other, and from the recent dramatic but spotty shift in the Valley from an agricultural to an industrial economy.

PHYSICAL CHARACTERISTICS

The Tennessee River drainage basin, figure 1, has an area of 40,910 square miles and includes portions of seven states. These states and the portion of the Valley contained in them are as follows: Alabama 16.6 percent, Georgia 3.6 percent, Kentucky 2.4 percent, Mississippi 1.0 percent, North Carolina 13.4 percent, Tennessee 55.1 percent, and Virginia 7.9 percent.

The main river, beginning at Knoxville at the confluence of the Holston and French Broad Rivers, flows southwestward through Chattanooga to Guntersville Dam, westward across northern Alabama to Pickwick Landing Dam, and thence northward to its outlet in the Ohio River at Paducah, Kentucky. Its major tributaries in the order of their confluence with the Tennessee River are listed in table 1.

The minor tributary streams all have drainage basins of less than 1,000 square miles, the largest being Bear Creek with 946 square miles of watershed in northern Alabama and Mississippi.

TABLE 1

MAJOR TRIBUTARIES OF TENNESSEE RIVER

Tributary	State of Origin	River Mile at Confluence	Tributary Drainage Area sq. mi.	Percent of Total Basin
Holston River	Virginia	652.1	3,776	9.2
French Broad River	North Carolina	652.1	5,124	12.5
Little Tennessee River	(North Carolina (Georgia	601.1	2,627	6.4
Clinch River	Virginia	567.7	4,413	10.8
Hiwassee River	Georgia	499.4	2,700	6.6
Elk River	Tennessee	284.3	2,249	5.5
Duck River	Tennessee	110.7	3,500	8.6
Total major tributary drainage			24,389	59.6

Physiography and Geology

Physiographically and topographically the region of the Tennessee Valley is as diverse as any region of equal size that could be found in the eastern United States. In elevation above sea level it ranges from 300 feet at its western extremity at Paducah, Kentucky, to 6,684 feet on Mount Mitchell, North Carolina, near its eastern boundary. Geologically, it ranges from a highly complex structure in the eastern portion to a comparatively simple structure in the middle and western portions. As shown in figure 2, the Tennessee Valley region may be divided into six physiographic subregions.

Appalachian Mountains--This high, rugged mountain subregion forms the eastern boundary of the Valley and contains much of the drainage

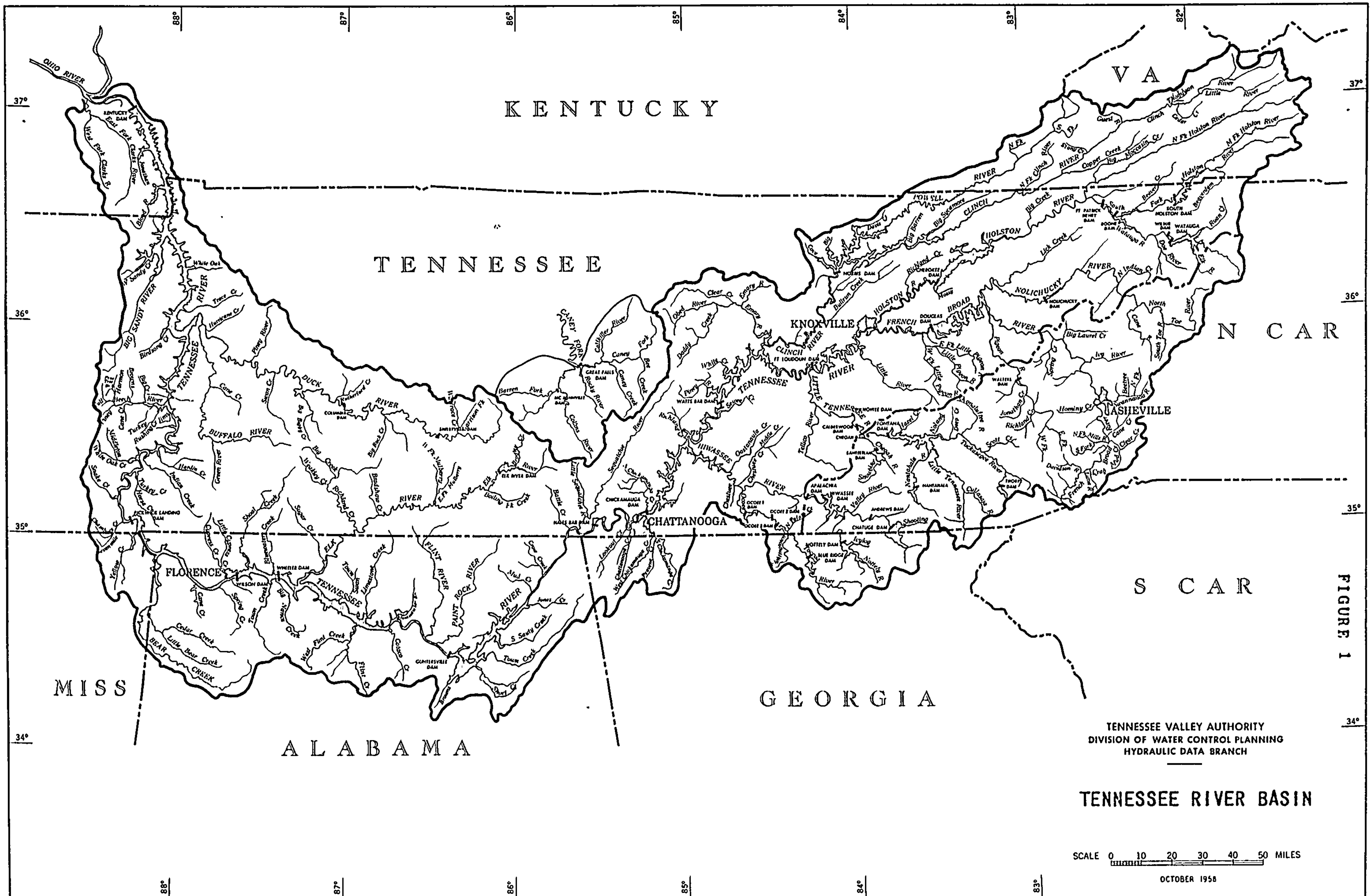
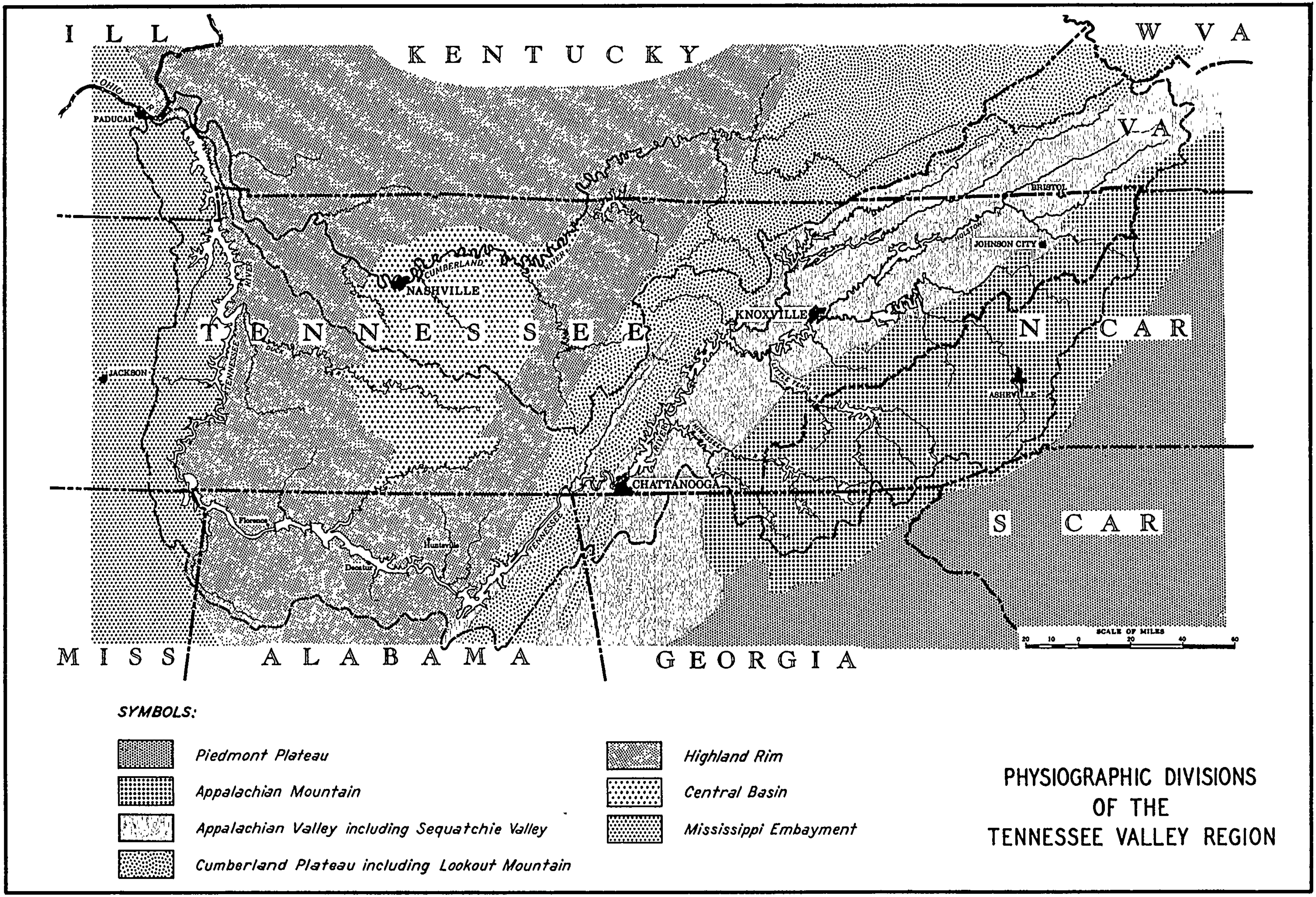


FIGURE 1
TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING
HYDRAULIC DATA BRANCH
TENNESSEE RIVER BASIN
SCALE 0 10 20 30 40 50 MILES
OCTOBER 1958
KENTUCKY
TENNESSEE
VA
N CAR
S CAR
GEORGIA
ALABAMA
MISS
KNOXVILLE
ASHEVILLE
CHATTANOOGA
FLORENCE
OHIO RIVER
TENNESSEE
CLINCH RIVER
HOLSTON
NOLICHUCKY
FRENCH BROAD
LITTLE TENNESSEE
HIWASSEE
DUCK RIVER
ELK RIVER
BUFFALO RIVER
BIG SANDY RIVER
CANEY FORK
FLINT RIVER
PAINT ROCK RIVER
37°
36°
35°
34°
88°
87°
86°
85°
84°
83°
82°

FIGURE 2



PHYSIOGRAPHIC DIVISIONS
OF THE
TENNESSEE VALLEY REGION

basins of the French Broad, Little Tennessee, and Hiwassee Rivers. It occupies 9,076 square miles or 22 percent of the Valley area.

Numerous peaks in the area exceed 5,000 feet in elevation and a substantial number, particularly in the Great Smoky Mountains area, rise above 6,000 feet. The mountain summits are generally rounded, and sharply pointed peaks are rare.

Geologically, the region is made up very largely of igneous and metamorphic rocks. These consist almost entirely of granites, schists, gneisses, quartzites, slates, and marble. The eastern portion is underlain largely by the Carolina gneiss, the central portion by the quartzites, graywacke, schists, phyllite, and gneiss of the Great Smoky formation, and the western portion by numerous quartzite and slate formations.

All of the rocks are very closely folded and faulted. Most of them are brittle and are extensively fractured.

Appalachian Valley--Also known as the Valley of East Tennessee and the Great Valley, this subregion contains most of the basins of the Clinch and Holston Rivers, the lower reaches of the three large mountain tributaries, and the minor drainage of the Tennessee River from Knoxville to northwest Georgia. It occupies 11,203 square miles or 28 percent of the Valley.

The subregion is characterized mainly by comparatively narrow parallel ridges and somewhat broader intervening valleys of northeast-southwest trend. The only exceptions to this type of topography are found in the area southeast of Knoxville and southeast of Athens and Charleston where the topography is "knobby." Elevations in the region range from 630 feet in the riverbed at Chattanooga to 4,700 feet on Clinch Mountain in the northeastern end.

Geologically, the Appalachian Valley is a region of highly deformed sedimentary rocks consisting mainly of limestones, dolomites, and calcareous shales. Joints are abundantly developed in all rocks of the subregion.

Cumberland Plateau--This subregion extends southwestward across the center of the Tennessee Valley in a belt ranging in width from less than a mile to 30 miles. Abrupt escarpments bound it on the east and west. Covering an area in the Valley of 3,787 square miles, or 9 percent of the total, it contains the drainage basins of the Emory River (a Clinch River tributary), the Sequatchie River, and numerous small streams flowing directly into the Tennessee River. Elevations range up to 4,100 feet on Little Black Mountain which forms the divide between the Tennessee and Cumberland River basins.

Geologically, the Plateau is developed on sandstones and shales, underlain by limestones and shales. The rocks are nearly horizontal except in a few places. Numerous faults occur and joints are abundantly developed.

Highland Rim--This subregion forms a circular belt or rim around the Central Basin. It makes up about 11,544 square miles or 28 percent of the Valley area and includes major portions of the Duck and Elk River basins and most of the Tennessee River drainage across northern Alabama.

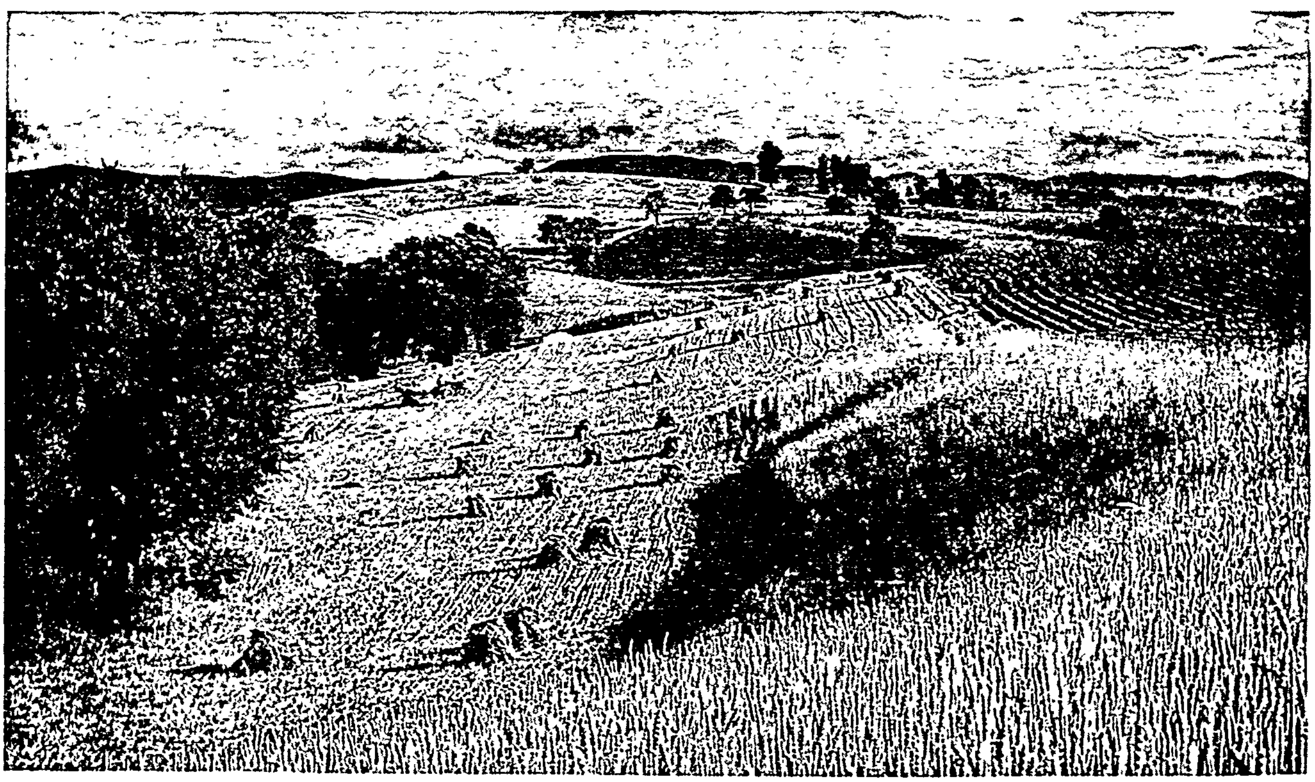
Physiographically, the Rim is a bench separated from the Central Basin by a steep escarpment and from the Cumberland Plateau by another steep westward facing escarpment. Except near its westward margin the surface is a gently rolling upland at an elevation of about 1,000 feet.

The entire eastern and southern part of the Highland Rim is developed on cherty limestones, very largely on the resistant Fort Payne chert. In the western part the underlying rocks are limestones, shales, and sandstones. The structure of the rocks is, on the whole, quite simple. Small folds are common but faults are rare.

Central Basin--The portion of the Central Basin which extends southward into the Tennessee Valley occupies some 2,002 square miles of the Duck and Elk River valleys. This is about 5 percent of the total Tennessee Valley area.

The Central Basin has been eroded out of an old peneplain surface which was originally at the general level of the Highland Rim. The relatively resistant cherty limestones of the Rim were removed and the broad, irregularly shaped basin was rapidly developed in the weaker underlying limestones. The surrounding escarpment is very irregular with many wide valleys running back

Forests cover 54 percent of the Valley, principally in the mountainous sections.



Forty-four percent of the Valley is open land ; nearly half of this is in pasture.

from the basin along the large streams. Ridges, still capped by the cherty limestones, extend out into the basin. Elevations on these ridges range up to about 1,100 feet while the main basin floor slopes from about elevation 900 on the east to about 400 on the west.

Most of the rocks are soluble, and sinkholes and solution channels abound. Faults are rare. Joints are developed in great number but they are not extensive.

Mississippi Embayment--This subregion is a part of the coastal plain province of the southeastern United States. The portion of it that lies in the Tennessee Valley is almost entirely west of the Tennessee River below Pickwick Landing Dam. It covers some 3,298 square miles of small tributary drainage basins on the west side of the river, or about 8 percent of the Valley. The relief is low, ranging generally between elevations 300 feet and 600 feet. The stream valleys are broad and flat and are filled with thick accumulations of alluvial material.

The rocks exposed in the subregion are unconsolidated gravels, sands, clays, and loess. Folds and faults are rare and, since the rock is unconsolidated, true joints do not exist.

Soils

As might be expected from the diversity of the parent rock and the relief, the soils of the Valley vary greatly from place to place. Slope, drainage, stoniness, and depth, all of which affect the suitability of a soil for agricultural uses, may change gradually or abruptly within a few feet. Drainage may be poor or excessive. Such extremes in soils may be found within the boundaries of a single farm.

Although the differences are more conspicuous, the soils of the Valley do have many important characteristics in common. Compared with the soils of the Midwest, for example, they are low in inherent fertility but are generally very responsive to good management. The surface soils are prevailingly light-colored and silt loam in texture; the subsoils are heavier textured, tougher, and red, yellow, or mottled in color. They are low in organic matter, the dark-colored surface layer of high organic matter content being very thin under forest cover and entirely missing in most cultivated areas. The soils are strongly leached, acid in reaction and, with a few exceptions, low in mineral plant nutrients.

Figure 3 shows the principal associations of the Valley. A soil association is a group of soils occurring together in a characteristic pattern. It may consist of a few soils or many. The soils may be similar or differ greatly, but in each area there is a certain uniformity of soil pattern.

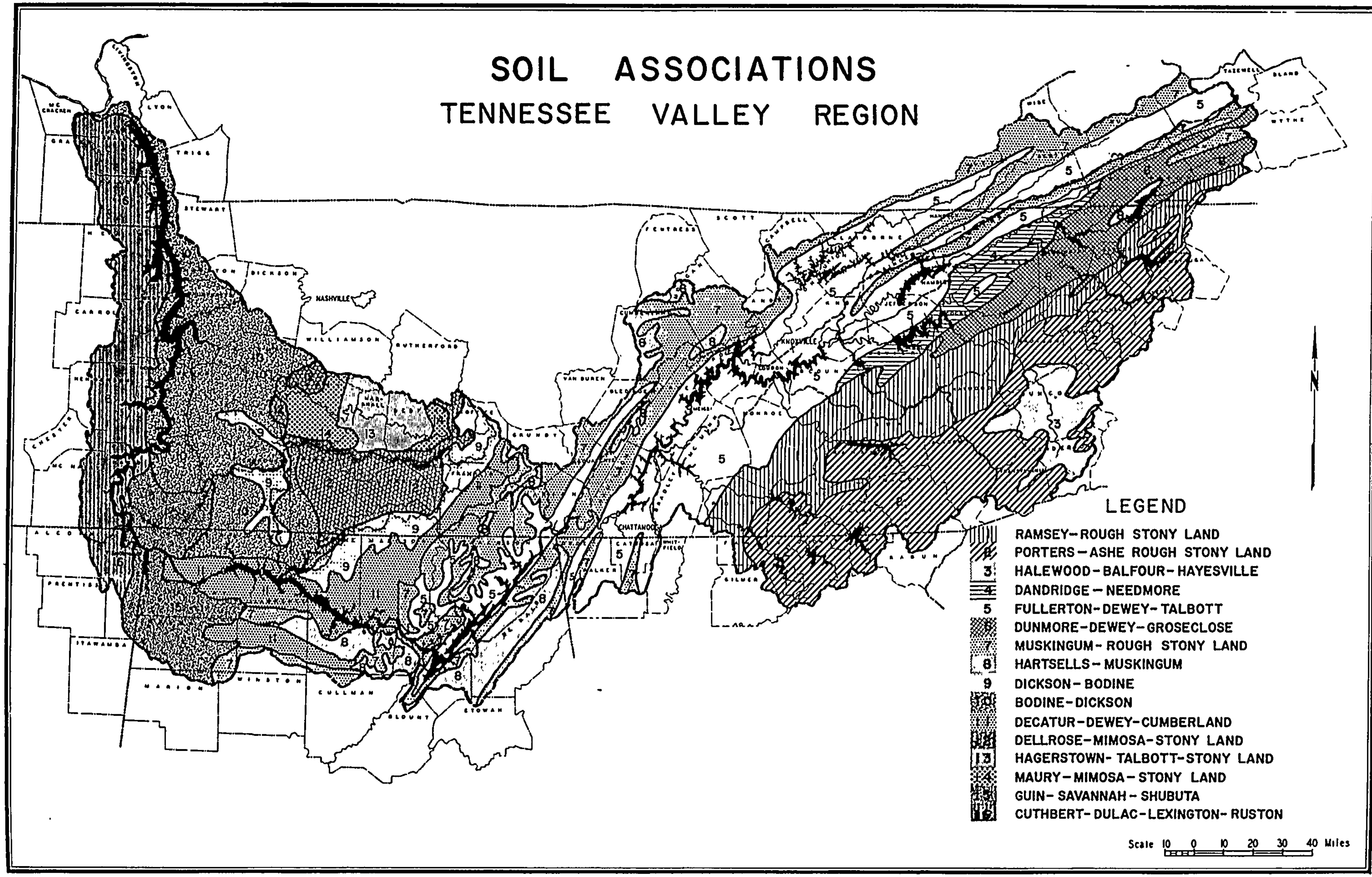
Land Use

Forests--Forests in the Valley cover 14,042,000 acres or 54 percent of the total area. As figure 4 shows, the dominantly forested regions of the Valley are the mountains of western North Carolina and eastern Tennessee, the coal mining area of southwestern Virginia, the Cumberland Plateau, and the western part of the Highland Rim in middle Tennessee, northeastern Mississippi, and northwestern Alabama. The eastern mountain sections have the heaviest timber volumes per acre.

The Valley is primarily hardwood country (figure 5). Its soil and climate are particularly suitable to the rapid growth of quality hardwood timber. Oaks make up over 40 percent of the total forest stand. Another third includes hickory, yellow poplar, the gums, maples, and beech. Shortleaf, loblolly, and Virginia pines are the principal conifers. The forest lands are 82 percent in private ownership. Small holdings predominate. Ninety-nine percent of all private ownerships are under 500 acres, and these small owners control almost 80 percent of the privately owned timber.

Three primary products--logs, pulpwood, and fuelwood--account for three-fourths of the commercial volume demand on the forest resource. In 1956, 1,600,000 cords of wood went into lumber and other sawed products, 850,000 cords into pulpwood, and 660,000 cords into fuel. Lumber production has been holding fairly steady in recent years; pulpwood production has shown an almost continuous rise, and use of wood for fuel has dropped sharply.

FIGURE 3



SOIL ASSOCIATIONS
TENNESSEE VALLEY REGION
LEGEND
1 RAMSEY-ROUGH STONY LAND
2 PORTERS-ASHE ROUGH STONY LAND
3 HALEWOOD-BALFOUR-HAYESVILLE
4 DANDRIDGE-NEEDMORE
5 FULLERTON-DEWEY-TALBOTT
6 DUNMORE-DEWEY-GROSECLOSE
7 MUSKINGUM-ROUGH STONY LAND
8 HARTSELLS-MUSKINGUM
9 DICKSON-BODINE
10 BODINE-DICKSON
11 DECATUR-DEWEY-CUMBERLAND
12 DELLROSE-MIMOSA-STONY LAND
13 HAGERSTOWN-TALBOTT-STONY LAND
14 MAURY-MIMOSA-STONY LAND
15 GUIN-SAVANNAH-SHUBUTA
16 CUTHBERT-DULAC-LEXINGTON-RUSTON
Scale 10 0 10 20 30 40 Miles
N
NASHVILLE
KNOXVILLE
CHATTANOOGA

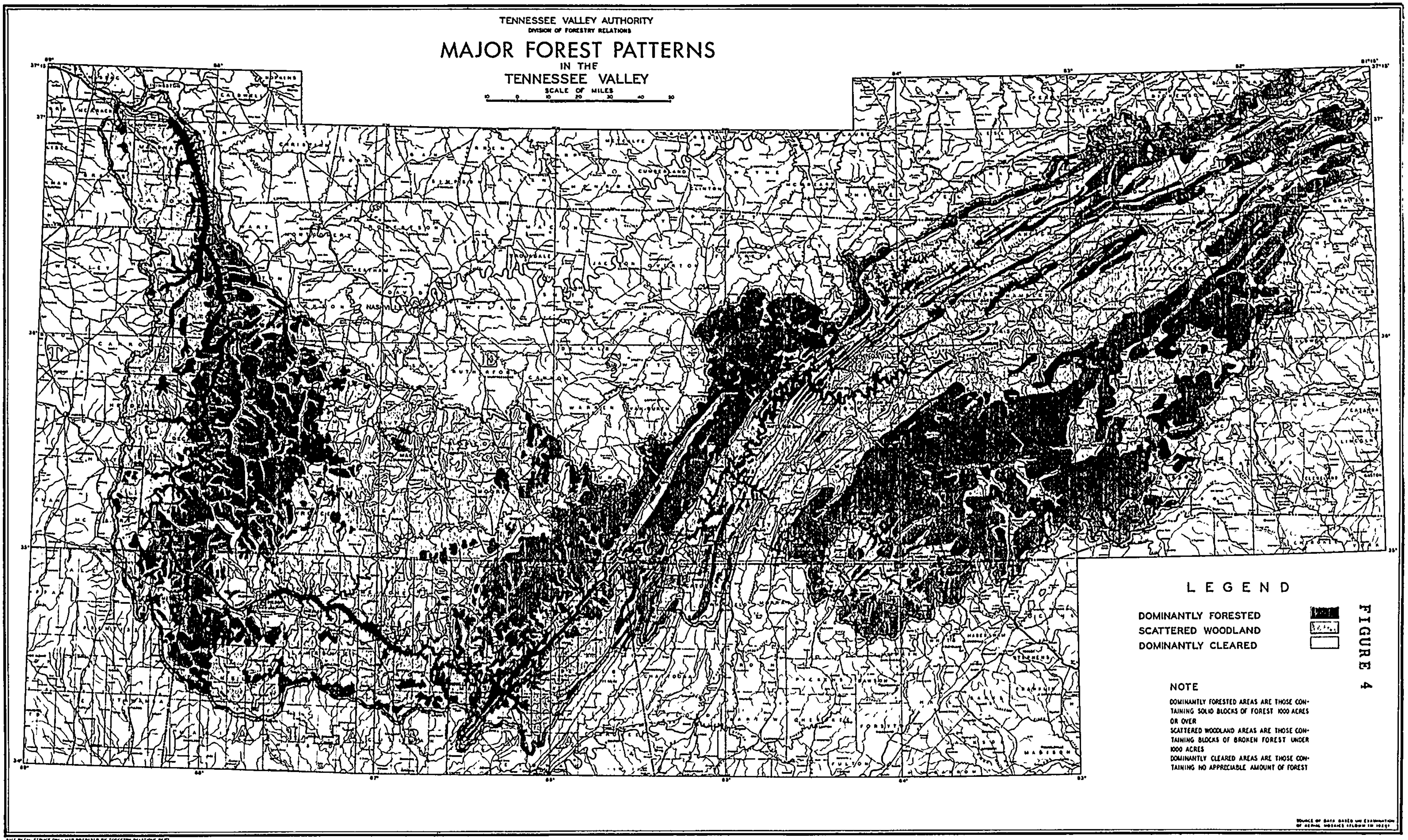
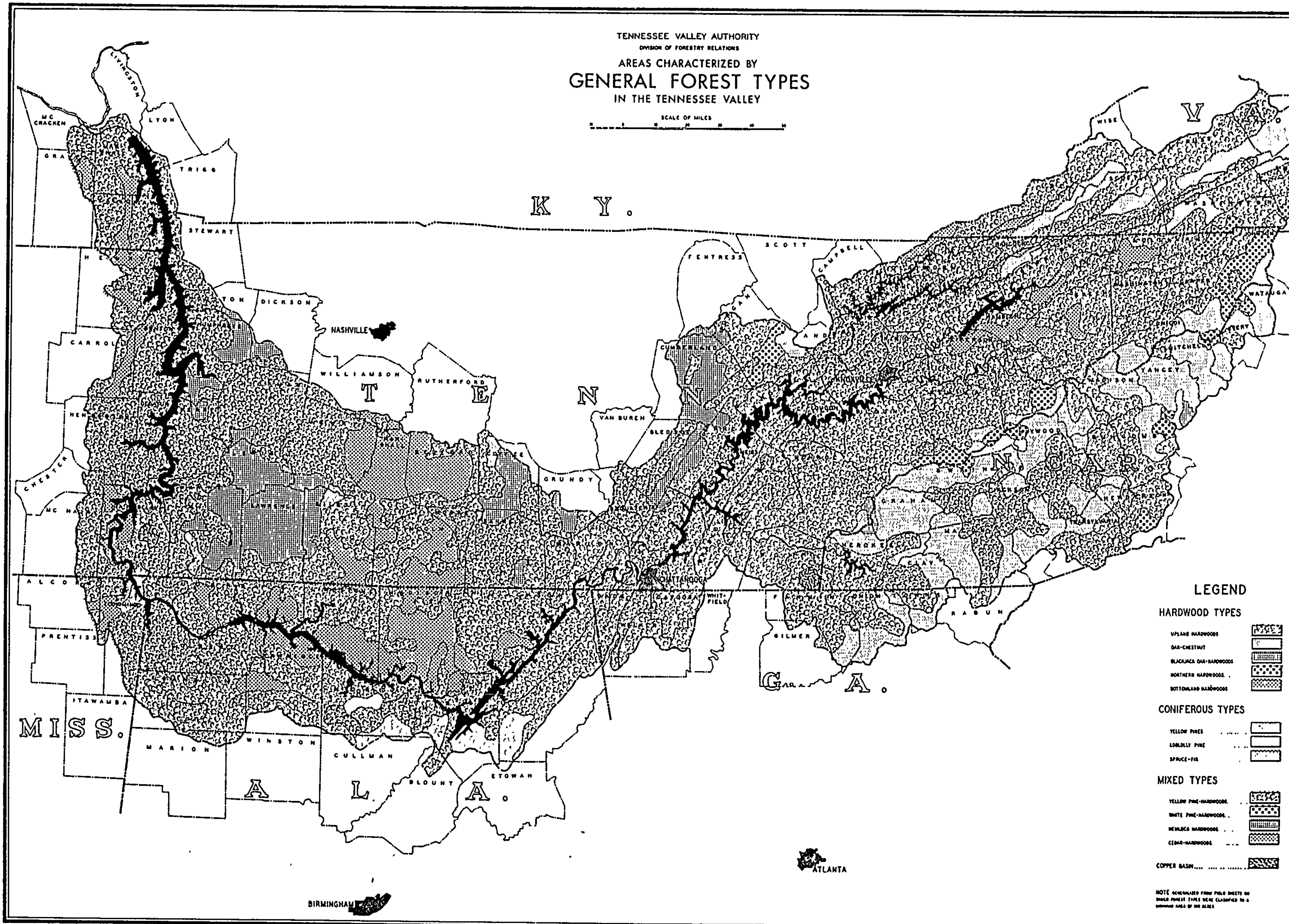

TENNESSEE VALLEY AUTHORITY
DIVISION OF FORESTRY RELATIONS
MAJOR FOREST PATTERNS
IN THE
TENNESSEE VALLEY
SCALE OF MILES
10 0 10 20 30 40 50
NASHVILLE
LEGEND
DOMINANTLY FORESTED
SCATTERED WOODLAND
DOMINANTLY CLEARED
NOTE
DOMINANTLY FORESTED AREAS ARE THOSE CONTAINING SOLID BLOCKS OF FOREST 1000 ACRES OR OVER
SCATTERED WOODLAND AREAS ARE THOSE CONTAINING BLOCKS OF BROKEN FOREST UNDER 1000 ACRES
DOMINANTLY CLEARED AREAS ARE THOSE CONTAINING NO APPRECIABLE AMOUNT OF FOREST
FIGURE 4
BASE BY ENG SERVICE DIV - MAP PREPARED BY FORESTRY RELATIONS DEPT

FIGURE 5



TENNESSEE VALLEY AUTHORITY
DIVISION OF FORESTRY RELATIONS
AREAS CHARACTERIZED BY
GENERAL FOREST TYPES
IN THE TENNESSEE VALLEY
SCALE OF MILES
K Y.
T E N N.
V A.
N. CAR.
G A.
A L A.
MISS.
NASHVILLE
ATLANTA
BIRMINGHAM
LIVINGSTON
MC CRACKEN
LYON
TRIGG
STEWART
DICKSON
WILLIAMSON
RUTHERFORD
VAN BUREN
GRUNDY
BLEDSOE
CUMBERLAND
FENTRESS
SCOTT
CAMPBELL
CARROL
CHESTER
ALCO
PRENTISS
ITAWAMBA
MARION
WINSTON
CULLMAN
BLOUNT
ETOWAH
WHITFIELD
GILMER
RABUN
WISE
TAZEWELL
WATAUGA
YANCEY
LEGEND
HARDWOOD TYPES
UPLAND HARDWOODS
OAK-CHESTNUT
BLACKJACK OAK-HARDWOODS
NORTHERN HARDWOODS
BOTTOMLAND HARDWOODS
CONIFEROUS TYPES
YELLOW PINES
LOBLOLLY PINE
SPRUCE-FIR
MIXED TYPES
YELLOW PINE-HARDWOODS
WHITE PINE-HARDWOODS
HEMLOCK HARDWOODS
CEDAR-HARDWOODS
COPPER BASIN

The Valley's forest area is gradually increasing. Almost 400,000 acres have been planted in the past 20 years, and some agricultural land is reverting naturally to forest. There is still some 657,000 acres of actively eroding land in the Valley in need of planting and another 774,000 acres of marginal open land better suited to timber production than to its present use.

Agriculture--Slightly over 60 percent of the land in the Valley counties is in farms, averaging 83 acres each at the time of the 1954 Census. Fifty-six percent of the land in farms is open, 39 percent is in woodland, and the balance is in farmsteads, roads, and other development.

In 1954, some 46 percent of the open land was pasture; row crops were grown on 28 percent, and 16 percent was in small grains and hay.

The land use pattern has been changing quite rapidly in the past few years in the direction of decreased cropland and increase in open pasture. There has been a sizeable decrease in corn and cotton acreage, a small to moderate decrease in tobacco and grain, and a substantial increase in hay acreage. Compensating somewhat for the reduction in crop acreage has been a significant increase in yields, particularly in tobacco. Accompanying the apparent trend toward a grassland type of farming has been an increase between 1950 and 1955 in the number of cattle, particularly beef, and a substantial decrease in the number of hogs.

Other Land Use--The extension of industrial areas and the spread of residential development around cities and along highways are taking lands formerly available for agriculture and forests. According to figures reported by the U. S. Department of Agriculture, Tennessee had seven million acres of cropland in 1950. At that time two-thirds of a million acres of land was used by urban communities and by highways and railroads. The new inter-state highway system includes approximately 1000 miles of road to be built in Tennessee. The right-of-way for this mileage will require some 350,000 acres of land without allowance for interchanges and for the industrial, commercial, and residential districts which it is expected will develop near the interchanges.

ECONOMIC CHARACTERISTICS

The Tennessee Valley region has been for many years a predominantly rural and agricultural economy; it has been a producer of raw materials rather than of manufactured goods. In several of the economic changes that produce increased use of water it has lagged behind the nation generally.

In the last 25 years and particularly since World War II there has been a steady change in the economy, characterized by urbanization and industrial growth, which is bringing the Valley much closer to the national economic pattern.

Population Shifts

For example, the non-farm population of the Valley has been increasing (up 519,000 from 1940 to 1950) and the farm population has been declining (down 285,000 in the same 10 years). In 1940 about half of the population was non-farm; in 1950 the non-farm population had grown to 63 percent. While the total population of the Valley increased only 8 percent from 1940 to 1950 and showed no change from 1950 to 1955, the 22 counties that include the largest cities increased 29 percent in the 15 years. This shift in population has thrown a heavier load on municipal water supply systems and has increased the over-all domestic use of water. In 1955 some 1,838,000 persons, about 60 percent of the Valley's 3,000,000 population, were being provided with water by municipal systems.

Per Capita Income

Another economic factor which has had an important but less direct effect on the use of water is the gain in per capita personal income in the last 15 years. Although the average per capita personal income in the Valley was still only 60 percent of the national average in 1955, it had gained since 1940 at a rate 40 percent in excess of the national average rate. The high percentage of low income farm workers and farm families in the Valley has in the past held the income lower than the national average. The sharp increase in personal and family income in recent years has resulted largely from the shift to a non-farm, industrial economy. The rising level of living that comes with rising income has brought with it a greater use of water in the home and greater activity among water-using trades and services.

Decline in Number of Farms

Paralleling the move from farm to city, there has been a general decline in the number of farms in the Valley. The total of 223,000 farms in 1954 was 12 percent less than in 1950. The decline apparently is a result of abandonment of the smaller commercial farms and some increase in the size of larger commercial farms. The 32,000 larger commercial farms with gross sales of over $2,500 accounted for more than 65 percent of all farm products marketed in the Valley in 1954. The operators of these farms are more apt to make maximum use of good management practices such as fertilizer, mechanization, and irrigation on a large scale. They are more likely also to install water distribution systems on their farms and to build farm ponds.

Manufacturing

There were 3,578 manufacturing establishments in the Valley in 1954. Counties in which industrial employment was highest were those situated along the Holston River and its major tributaries downstream to Knoxville; along the Tennessee River from Knoxville to Wilson Dam and below Kentucky Dam; in the Duck River basin, and in the upper French Broad River basin. A substantial number of these establishments were in the "wet" industry class, those using large amounts of water for processing and cooling. Included in this category are the pulp and paper mills, the synthetic fiber plants, the food processers and canners, and the chemical and metal industries. These are also the high wage industries, paying some 65 percent higher average compensation per worker than the industries making textile mill products, apparel and related products, lumber and wood products, furniture and fixtures, and leather and leather goods. Fifty-two percent of the Valley's production workers are now employed in these low wage industrial groups as compared to 26 percent in the nation. This is another factor contributing to the prevailing low income status of the Valley.

The outstanding industrial growth in recent years in the Valley has been among the high wage, high production, large water using industries. These industries, drawn to the Valley by its abundance of raw materials from farm, forest, and mine, its water resources, its available labor force, and its low-cost power are helping to raise the living standard of the region.

Outlook for 1975

Some projected future economic developments are:

1. Agriculture seems certain to provide employment for fewer people in 1975 than now. Farming is becoming more of a business enterprise than in the past. Fewer and larger farms, higher capital investment per farm, greater uses of fertilizers, and increased mechanization point toward more efficient operations and higher average per farm incomes. Total farm production will probably increase, with gains primarily in livestock and livestock products.

Many small commercial farms will become large commercial farms through consolidation, or cease to exist as farms. The number of farms classed as part-time is likely to decrease, although the practice of part-time farming will increase in the regions of industrial development. The primary influences in the timing and rate of farm population changes are expected to be of a non-farm character.

2. Considerable economic development will take place in the forest industries as a result of the changes in farming, the better utilization being made of trees, and the trend toward improved forest management. The resources available for these forest industries are growing resources, and it is expected that there will be important developments in their use.

3. The best prospects for future manufacturing growth in the Valley appear to be in the "high wage" industries, such as chemical and related products, metal fabricating and processing, pulp and paper, and machinery and transportation equipment. These industries often form clusters, and their future growth can be expected to occur in and around the present urban and industrial areas. The "low wage" industries, which account for half the manufacturing employment

in the Valley, are widely scattered over the area and comprise numerous small plants. Although these industries are expanding, they are tending to decline in relative importance.

4. Available resources suggest dramatic possibilities in the development of one or more major industrial centers and in new or expanded national defense establishments. Such happenings are not predictable but they are the type of developments which have occurred in the past and which may occur in the future.

5. Trade and service industries can be expected to grow more rapidly than manufacturing. Their growth, however, will depend on incomes from manufacturing as well as from other sources.

6. The projected 1975 Valley population is expected to increase from 3 million in 1955 to a range between 3.5 million and 3.9 million, of which the non-farm population will be around 3 million persons.

SUBAREAS OF THE BASIN

To develop the differences between areas in the analyses of data for this study, the Tennessee River Basin has been separated into 10 subareas as shown on figure 6. Areas Nos. 1, 3, and 5 cover segments of the Tennessee River together with the minor drainage tributary to the river. Nos. 2, 4, 7, 8, 9, and 10 include the basins of the 7 major tributaries of the Tennessee River. No. 6 covers two streams, the Emory and Sequatchie Rivers, which drain the greater part of the Cumberland Plateau within the Tennessee Valley. Water resource characteristics of this Plateau area are sufficiently different from those of the adjoining basins to justify this separation.

Table 2 shows the size of each area and the proportion of open land, forest, and water surface in each.

TABLE 2

TENNESSEE RIVER BASIN SUBAREAS

PHYSICAL DATA

Area*	Drainage Basin	Proportion of Valley	Proportion of Land and Water		
			Open Land	Forest	Water
	sq. mi.	percent	percent	percent	percent
1	4,560	11.1	44.5	50.0	5.5
2	3,500	8.6	47.1	52.6	0.3
3	6,120	15.0	49.9	47.0	3.1
4	2,250	5.5	65.0	34.3	0.7
5	4,860	11.9	41.8	53.4	4.8
6	1,460	3.5	21.4	78.3	0.3
7	5,330	13.0	26.1	72.2	1.7
8	3,550	8.7	50.4	47.7	1.9
9	3,780	9.2	51.4	46.3	2.3
10	5,500	13.5	41.3	57.4	1.3
	40,910	100.0	43.8	53.7	2.5

*See figure 6 for name and location of areas.

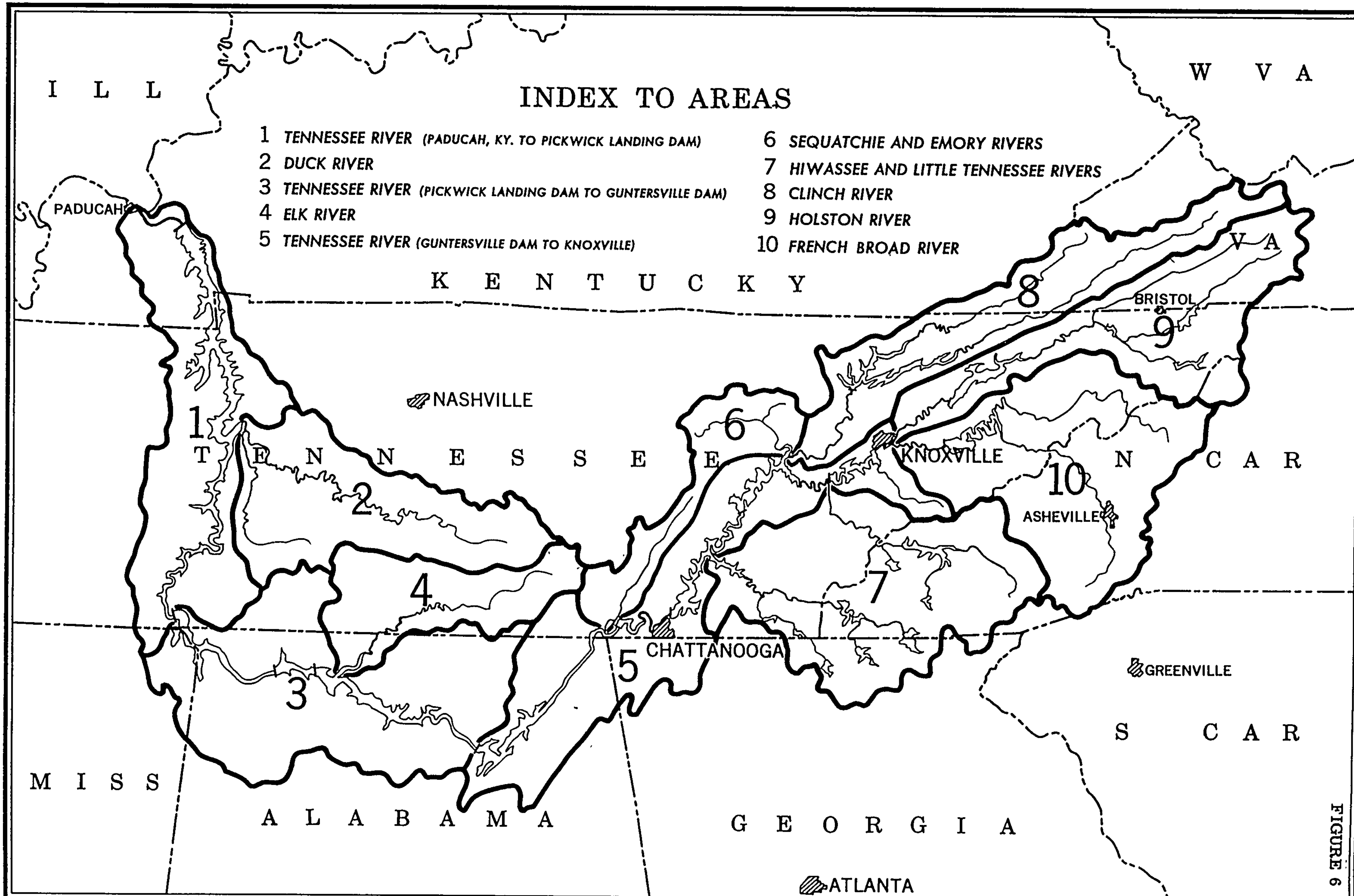

INDEX TO AREAS
1 TENNESSEE RIVER (PADUCAH, KY. TO PICKWICK LANDING DAM)
2 DUCK RIVER
3 TENNESSEE RIVER (PICKWICK LANDING DAM TO GUNTERSVILLE DAM)
4 ELK RIVER
5 TENNESSEE RIVER (GUNTERSVILLE DAM TO KNOXVILLE)
6 SEQUATCHIE AND EMORY RIVERS
7 HIWASSEE AND LITTLE TENNESSEE RIVERS
8 CLINCH RIVER
9 HOLSTON RIVER
10 FRENCH BROAD RIVER
ILL
W VA
PADUCAH
KENTUCKY
VA
BRISTOL
NASHVILLE
TENNESSEE
KNOXVILLE
N CAR
ASHEVILLE
CHATTANOOGA
GREENVILLE
S CAR
MISS
ALABAMA
GEORGIA
ATLANTA
1
2
3
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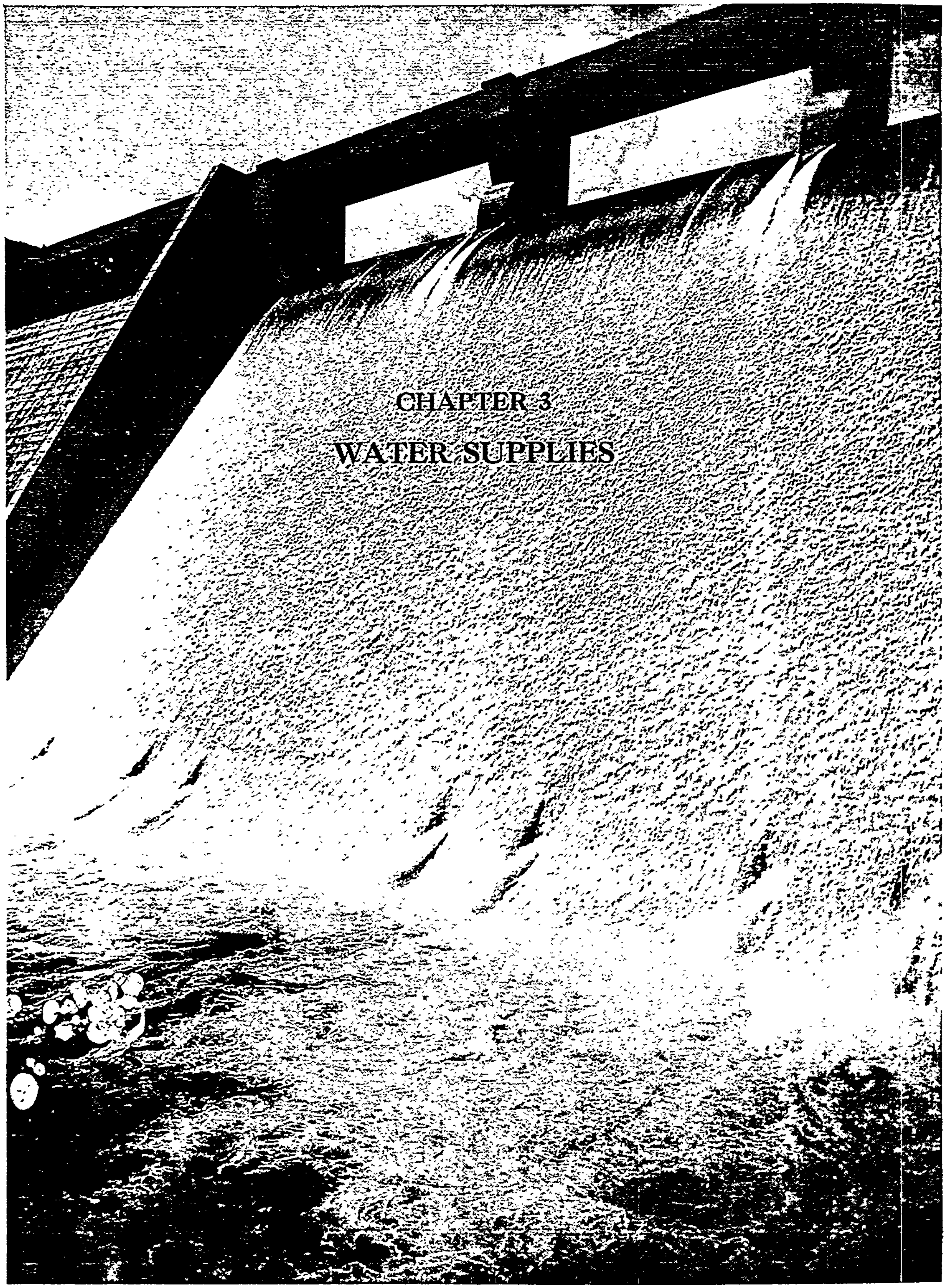
FIGURE 6


CHAPTER 3
WATER SUPPLIES

CHAPTER 3

WATER SUPPLIES

The collection of basic data on the water supplies of the Tennessee Valley has been carried on for many years but most intensively in the last 25 years. The present precipitation station network, for example, numbers approximately 570 gages of which TVA operates about 400. Less than 100 gages were in operation prior to 1933. Some of these old records extend back more than 80 years.

About 100 streamflow measuring stations were operated in the Valley by the U. S. Geological Survey prior to 1933. The oldest of these was established in 1871. Since 1933 additional gages have been installed, and the present network numbers about 190 stations. Drainage areas measured range from a few acres to over 40,000 square miles. In addition to these continuous records of streamflow, the two agencies have made hundreds of miscellaneous determinations of low flow and flood peak discharges on small ungaged streams in the Valley. Much data on the height of past floods have been collected along the major tributaries and on many smaller streams where these flow through urban areas.

Since 1935 the TVA has measured evaporation from water surfaces at ten locations in the Valley. Sampling of water quality and observation of water temperature has been carried on in streams and reservoirs throughout the region. Storms and floods have been investigated and many special studies have been made to learn more about the Valley's water resources.

To briefly summarize the huge mass of data thus accumulated necessarily requires a good deal of over-simplification. Only the broad area averages and extremes can be included, and critical details of time and place variations can barely be suggested. The following discussion, therefore, is intended to present only a general picture of the water resource situation in the Valley. Detailed information, where needed, are available in the files of TVA, the U. S. Geological Survey, the U. S. Weather Bureau, and other state and Federal agencies.

PRECIPITATION

The Tennessee River Basin is one of the wettest regions of the United States. Five of the Valley states are included in a listing of the country's ten wettest and all seven are ranked among the wettest twenty states.

Annual Means and Extremes

The mean annual rainfall over the Valley is 51.6 inches, based on 68 years of record through 1957. During these 68 years, the annual totals ranged from 64.6 inches in 1957 to 37.9 inches in 1941. Other wet years with over 60 inches of rainfall were 1920, 1932, and 1950. Other dry years with less than 40 inches were 1925 and 1930.

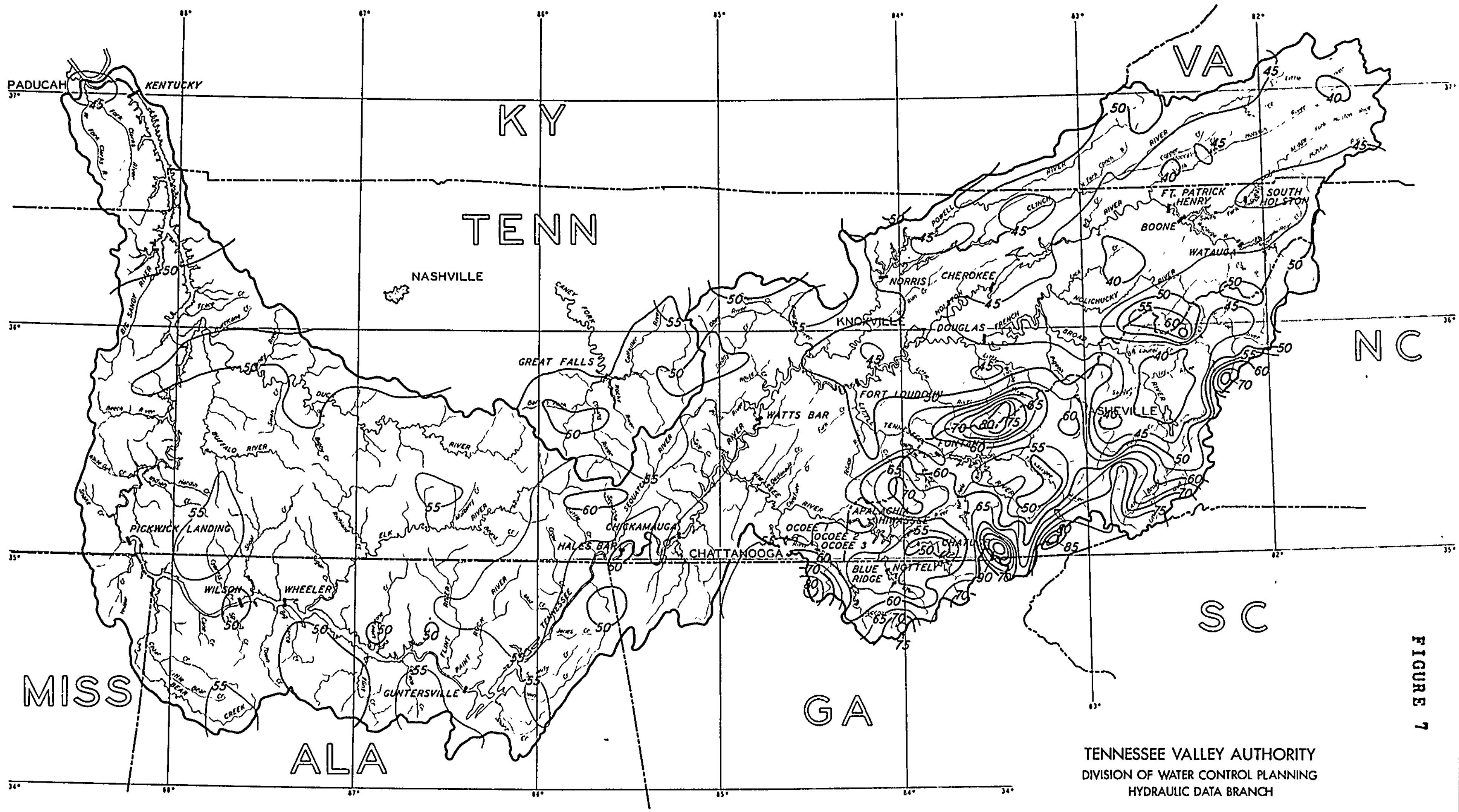
The areal distribution of mean annual rainfall over the Valley is shown in figure 7.

Topographic Effect--Although the isohyetal lines or lines of equal rainfall in figure 7 can only suggest the effects of topography on rainfall in the Valley, these effects are quite important. Their influence divides the Valley into three rather distinct areas as far as precipitation characteristics are concerned. One of these is the area of uniform rainfall and comparatively low relief west of Chattanooga. Here the annual rainfall is about 52 inches, practically identical with the Valley average, and the range in annual averages over the area is generally less than 10 inches.

Contrasted with the even distribution of rainfall in the western area is the extreme variation in annual means in the mountainous southeastern section, headwaters of the French Broad, Little Tennessee, and Hiwassee Rivers. Here, where the orographic or mountain influence is at a maximum, the range in annual average rainfall is from under 40 inches to over 90 inches with differences of as much as 30 inches occurring in a distance of 10 miles or less. Average rainfall in this area is about 10 percent above the Valley average.

North of this mountainous section is an area of uniform but lower rainfall covering most of the drainage basins of the Clinch and Holston Rivers

FIGURE 7



SYMBOLS:

75 Rainfall in Inches

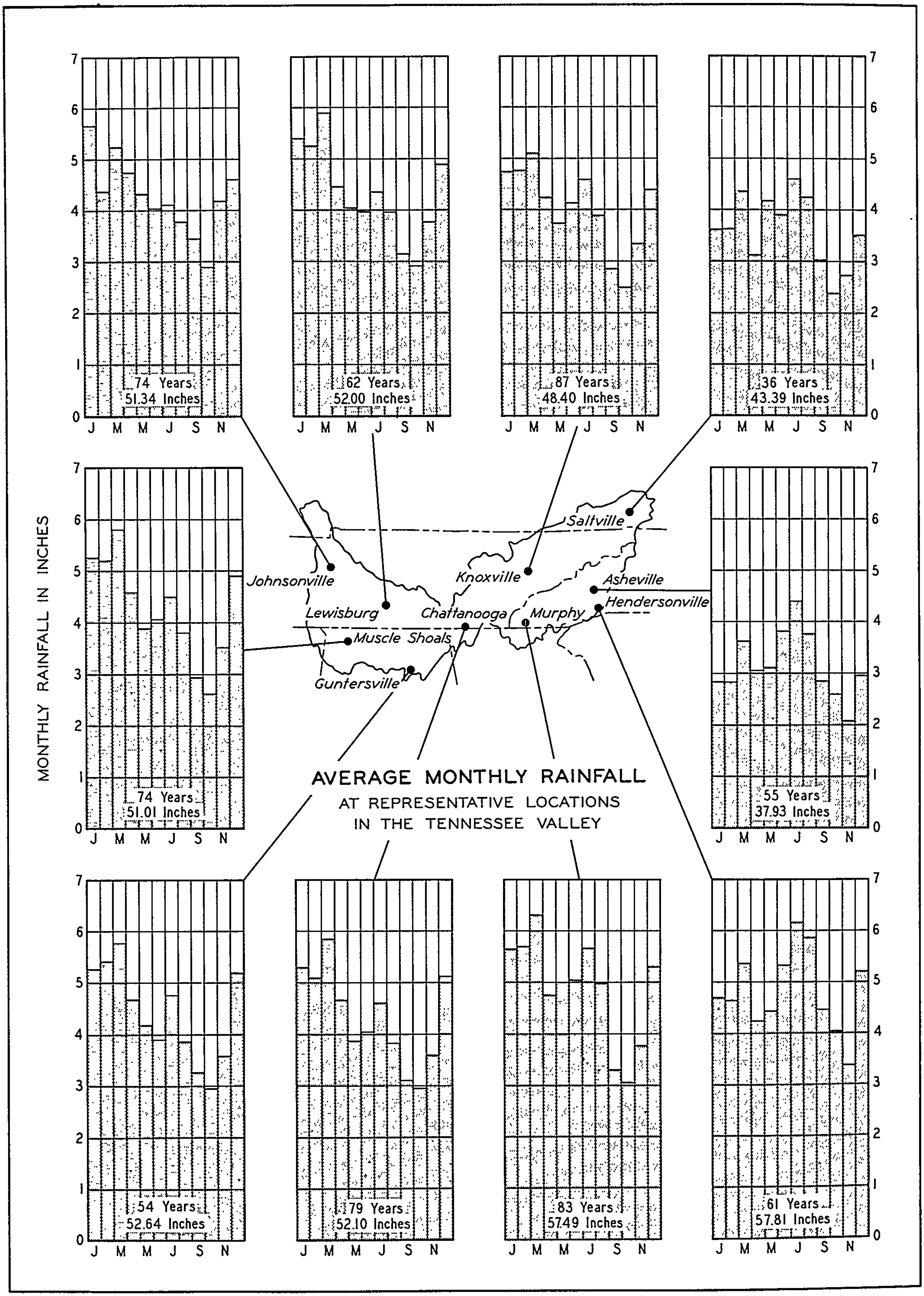
State Lines

Dams

TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING
HYDRAULIC DATA BRANCH

TENNESSEE RIVER BASIN
MEAN ANNUAL PRECIPITATION
20—YEAR PERIOD 1935—1954
SCALE 0 10 20 30 40 50 MILES

FIGURE 8



AVERAGE MONTHLY RAINFALL
AT REPRESENTATIVE LOCATIONS
IN THE TENNESSEE VALLEY
MONTHLY RAINFALL IN INCHES
Saltville
Knoxville
Asheville
Hendersonville
Murphy
Chattanooga
Johnsonville
Lewisburg
Muscle Shoals
Guntersville
74 Years
51.34 Inches
62 Years
52.00 Inches
87 Years
48.40 Inches
36 Years
43.39 Inches
74 Years
51.01 Inches
55 Years
37.93 Inches
54 Years
52.64 Inches
79 Years
52.10 Inches
83 Years
57.49 Inches
61 Years
57.81 Inches
J M M J S N

and the lower part of the French Broad River. Mean annual precipitation in this section is some 10 percent less than the Valley average, largely because of the shielding effect of the mountains to the southeast. As in the western area, the range in average annual rainfall from place to place is generally less than 10 inches.

The highest annual rainfall measured in the Valley occurs at the Coweeta No. 8 station in the mountainous headwaters of the Little Tennessee River. The average for 22 years through 1957 at this location is 92.3 inches. The maximum for a single year at Coweeta No. 8 was 126.1 inches in 1949. The greatest yearly total ever recorded in the Valley was 133.3 inches in 1957 at Haywood Gap, North Carolina, about 50 miles east of Coweeta.

Lowest annual rainfall in the Valley occurs in Buncombe and Madison Counties in the French Broad River drainage north of Asheville, North Carolina. Gages in this area record annual averages of less than 39 inches. The lowest amount recorded in the Valley in a single year was 18.7 inches in 1941 at Colesville, Tennessee, in the upper Holston River area.

Growing Season Rainfall

Average growing season (April-September) rainfall in the Valley is 25.1 inches, almost half of the annual total. The wettest growing season was in 1920 with 34.5 inches; the driest was in 1925 with 14.9 inches. One of the severest droughts of record occurred in the region in 1925, and many streams dropped to the lowest levels ever known. The longest series of subnormal growing seasons in 68 years were those of 1951 through 1956. The season of 1954 was the third driest of record.

Monthly Variations

Figure 8 shows typical patterns of monthly rainfall distribution at stations in various parts of the Valley. Of particular interest is the heavy June, July, and August rainfall in the eastern section. At Saltville, Asheville, and Hendersonville, July is the wettest month of the year. Westward, this summer rainy period becomes less and less pronounced until, at Johnsonville, it no longer shows up as a distinctive period.

The heaviest monthly rainfall of record over the whole Valley was 12.0 inches in January 1937. The wettest month over a segment of the Valley was July 1916 when three stations in the headwaters of the Hiwassee and Little Tennessee Rivers registered over 35 inches. At one of these stations, Altapass, North Carolina, 22.2 inches of rain fell in 24 hours on July 15-16, 1916.

Monthly precipitation of less than 0.1 inch sometimes occurs, usually in September and October. Some locations in the western section have experienced entire months without measurable rain.

Frequency of Daily Precipitation

Measurable precipitation falls in the Valley on an average of about 115 days per year. Roughly 55 of these days are in the six-month growing season, April-September. There appears to be some correlation between elevation and number of rainy days. For example, in the 1956 growing season, stations at an elevation 500 feet above sea level experienced 35 to 45 days of rain. Those at 1000 feet elevation had 50 to 60 rainy days, those at 2000 feet elevation had 60 to 70 rainy days, and the highest gages, those above 6000 feet elevation, had rain on 75 to 85 days in the season.

EVAPORATION AND TRANSPIRATION

Nature has the first claim on the rain that falls on the surface of the Valley. Her "take" is a lump sum rather than a fixed percentage, and it consists largely of the moisture evaporated from water surfaces, soil, and vegetation and that taken up and transpired by plants. No matter whether the area receives 90 inches of rainfall as at Coweeta or 40 inches as at Asheville, evapotranspiration still takes the first 25 to 35 inches. Over the Valley as a whole the average of this loss is 29 inches. Probably three-quarters of this amount is taken in the growing season when temperatures are high and vegetation is active. Only the absence of available water brought about by severe drought can reduce the losses due to evaporation and transpiration.

Evaporation from Water Surfaces

For the past 23 years evaporation from water surfaces has been measured at observation stations distributed over the Valley. These measurements show that, when water is constantly available in an exposed pan, as much as 46 or 47 inches of water depth will evaporate yearly in the western part of the Basin. In the cooler eastern section the annual evaporation may be as low as 39 or 40 inches on the average. Maximum monthly evaporation occurs in the hot months of June or July, and the lowest amounts come in January or December. Between 72 and 75 percent of the annual total loss comes in the six months April-September.

Evaporation from a reservoir surface is somewhat less than that from an exposed pan; experiments have indicated a factor of about 70 percent. Applying this factor, the evaporation from the reservoirs in the western part of the Valley will average 30 to 33 inches and from those in the eastern section 28 to 30 inches of water depth. The total loss in volume in 1956 from 50 major and minor reservoirs in the Valley has been estimated at 1,425,000 acre-feet or 460 billion gallons. This was nearly three and one-half percent of the total flow of the Tennessee River at its mouth in that year.

Evapotranspiration

Hydrologists have various names for the summation of the demands of evaporation, transpiration, and other losses from a watershed. One name commonly used is evapotranspiration; others are total evaporation and consumptive use.

When the total of evaporation losses was computed at 31 typical gaging stations in the Valley for the period 1935-1954 the average amounts were found to vary between 25 and 35 inches. It did not seem to make any consistent difference whether the rainfall was 70 inches or 50 inches or whether the drainage area was 50 square miles or 2,500 square miles.

DROUGHT

Drought occurs when the precipitation is not sufficient to meet Nature's demands of evaporation and transpiration. The Tennessee Valley is a region of apparently adequate crop season rainfall in most years, yet drought damages crops in the region with surprising frequency. Even though 25 inches of rain may fall in a growing season, crops may suffer from poor distribution in the critical periods.

Dr. C. H. M. van Bavel,[1] who has conducted intensive analyses of drought in the Southeast, defines agricultural drought simply as a condition where there is insufficient available soil water in the root zone to provide optimum growth by the plant. The method he used in determining drought takes into account the available soil moisture and evapotranspiration in an area as well as the rainfall.

Using this method and April-October rainfall records for the 30 years 1927-1956, computations of drought have been made for 28 locations in the Valley. Analysis of the data for soils holding three inches of available moisture in the root zone (the approximate average for the Valley), reveals several important relationships. There was, for example, only a general relation between number of drought-days and growing season rainfall; much depended on the evenness of distribution of the rainfall through the season. There were substantially less drought-days for a given amount of growing season rainfall in the eastern half than in the western half of the Valley. This was due largely to the lower temperatures and greater frequency of rainfall resulting from the higher elevations in the eastern section. Drought rarely if ever occurred in April, assuming the soil moisture level to be at a maximum on April 1. Drought was relatively rare in May until after the middle of the month. The median number of drought-days in April-October for a 3-inch soil moisture base ranged from 5 to 30 days in the eastern section and from 30 to 60 days west of Chattanooga.

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1. C. H. M. van Bavel, Agricultural Drought in North Carolina, Tech. Bul. No. 122. (Raleigh, N. C., North Carolina Agricultural Experiment Station, 1956).

STREAMFLOW

The water that flows in the streams of the Valley is the residual part of the precipitation that remains after the demands of evaporation, transpiration, and deep seepage have been satisfied. During and after a rain this water may flow directly over the surface into streams as surface runoff, or it may sink down to the vast ground-water reservoir to come out into the stream channels later as ground-water runoff. It is from this highly variable quantity of water that most users in the Valley must draw their supplies.

For comparison with rainfall it is convenient to measure volume of runoff in inches of depth over a drainage basin. We say, for example, that the annual runoff of a stream is 22 inches. This means that if all the water that flowed in the stream in a year were collected and spread out over the drainage basin of that stream it would cover every square mile and every acre to a depth of 22 inches.

Annual Runoff

The average annual discharge of the Tennessee River at Kentucky Dam for the 66 years 1891-1956 is 65,600 cubic feet per second. This is a total annual volume of 48 million acre-feet, 16 trillion gallons, or a depth of 22.2 inches over the 40,200 square miles above the dam. The Tennessee River carries nearly as much water in an average year as the Missouri River which has 13 times as large a drainage basin.

In the wettest year, 1920, the runoff of the Tennessee River was 34.2 inches or 54 percent above the normal. In the driest year, 1941, it was 10.7 inches or 52 percent under the normal. Rainfall in these two years was 65.9 inches and 37.6 inches, respectively.

Variation with Rainfall--If all the known determinations of average annual runoff are spotted on a map of the Valley, a relationship with the rainfall map of figure 7 is quite evident. In the western half where the rainfall spread is from 45 to 60 inches, the runoff ranges from 17 to 29 inches. In the northeast where rainfall generally ranges between 45 and 55 inches the runoff varies from 15 to 25 inches. And in the rugged southeastern region where 40 to 45 inches of rain falls in the valleys and 80 to 90 inches on the mountains, the runoff is as low as 10 inches and as much as 53 inches per year.

Approximately 30 to 45 percent of the measured runoff in the Valley occurs in the growing season April-September. The higher percentages occur in the eastern half of the Valley.

Monthly Variations in Runoff

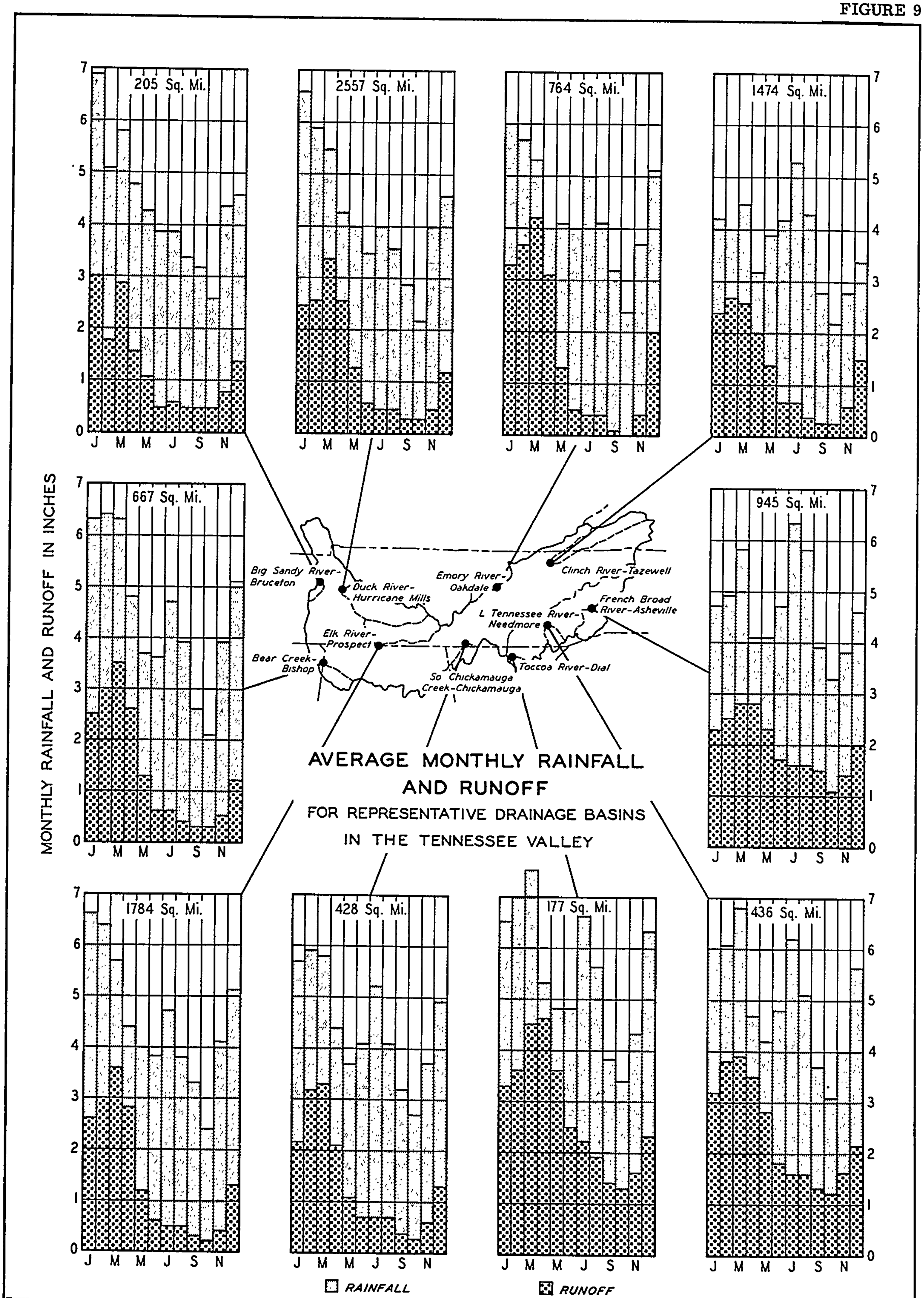
The average monthly runoff from ten representative drainage basins in the Valley is presented in figure 9. Also shown is the average monthly rainfall that produced this runoff. These typical patterns of runoff show certain significant distribution characteristics. These are: (1) high monthly flows come principally in the January-April period with a maximum usually in March; (2) lowest flows occur generally in September and October; (3) streams in the southeastern mountains maintain higher runoff through the growing season than anywhere else in the Valley, and (4) lowest crop season runoff occurs generally in the Cumberland Plateau and the Central Basin areas.

Low Flow Period

When examining the low flow record of the Valley streams it is well to keep in mind that the maximum demand for irrigation water comes in June, July, and August while streamflows are usually still above the annual minimum, and that the peak municipal use comes in August.

Nearly all gaging stations where records began before 1925 experienced the lowest daily discharge of record in September or October of that year. At stations established since 1925 the record low daily flow occurred with greatest frequency in September or October 1954.

Many small to moderately sized streams in the Valley go completely dry in the fall of drought years. During the five years 1952 through 1956 over 250 streams in the Alabama, Kentucky, Mississippi, and Tennessee portions of the Valley were observed to be dry one or more times. Largest of these was



AVERAGE MONTHLY RAINFALL AND RUNOFF FOR REPRESENTATIVE DRAINAGE BASINS IN THE TENNESSEE VALLEY the 764-square-mile basin of the Emory River above Oakdale, Tennessee, which had no flow for six consecutive days in October 1953 and for 15 days in November 1953.

Flood Occurrences

Major Valley-wide floods on the Tennessee River are limited almost exclusively to the months December through April. This general pattern holds for nearly all streams with drainage basins greater than 200 or 300 square miles except for the rivers that head in the mountains of the southeastern Valley divide. In this mountain region devastating floods may also occur during the summer and fall from intense rains accompanying the passage of hurricane storms or from widespread and severe thunderstorms. On small streams floods are likely to occur in any month of the year.

A vast amount of data on flood heights and flood discharges on the smaller streams of the Valley have been collected by the TVA and the U. S. Geological Survey. These data show that, for a given size of drainage basin, maximum known flood peak discharges have been almost twice as great on the small streams in the southeastern mountains as on those in the northeastern area. In the western half of the Valley, the experience has shown maximum discharges per square mile nearly as high as in the southeast.

GROUND WATER

For the purpose of this study, ground water has been considered to mean only the water taken manually or mechanically from wells and not the water that flows freely from springs. While water from springs comes from ground-water sources, so also does the low flow of the creeks and rivers which is classed as streamflow.

Ground water from wells furnishes most of the farms of the Tennessee Valley with domestic supplies and many of the smaller municipal systems. Records show that 181 public water supplies use either wells or spring flow as a sole source. With few exceptions, however, the yield from these wells rarely exceeds 200 or 300 gallons per minute and the majority provide less than 50 gallons per minute.

An example of the shortage of adequate water supplies from wells in the Tennessee Valley is given by a 1957 inventory of irrigation systems which showed that only four percent of nearly 1,000 systems used water from wells. The only important volume of use from this source was that in Madison and Limestone Counties in Alabama. Also, an investigation of water supply systems in the Valley serving 1,000 or more people showed that only 10 percent of the total volume was being taken from wells.

Perhaps the best over-all picture of the ground-water situation in the Valley can be obtained from the following brief comment on each physiographic region within the Valley.

Appalachian Mountains--Ground water does not occur in sizable volumes except in very limited areas underlain by the cavernous Murphy marble. The several siliceous rocks of igneous and metamorphic origin contain very little ground water. In these rocks, small yields are produced from wells which are drilled into the more permeable layer just above bedrock.

Appalachian Valley--Small to modest yields may be obtained in this region from wells less than 300 feet deep, but large yields are the exception rather than the rule. Occasional wells which yield large flows result from the perforation, by chance, of either fracture zones or solution channels. Wells in limestone terrains, such as this is, frequently yield muddy water during and following heavy rains.

Cumberland Plateau--A small amount of water soaks into the more weathered portions of the sandstones in this region, but the shale strata limit its downward movement. Shallow wells afford small yields and are generally not very reliable. Deep wells are unproductive.

Highland Rim--The permeability of the chert in this region and the presence of fractured and soluble limestone at depths favor the accumulation of ground water. Wells drilled in the valleys are productive of modest to good yields. Substantial yields are presently being obtained from wells in Limestone and Madison Counties in the Alabama portion of the Highland Rim. This is particularly true of those in the Fort Payne chert formation.

Central Basin--Topographically, this basin is an excellent catchment area. Joints in the underlying limestone are everywhere well developed, although they are not open to depths of more than 100 or 200 feet. Solution channels are present but they are not so extensively developed as in areas of more highly deformed rocks. Consequently, the volume of available ground water is smaller than might be expected. Wells yield modest quantities of water and large yields are exceptional.

Mississippi Embayment--The unconsolidated deposits along the western side of the river in Tennessee are not very productive of ground water, but the underlying limestones are somewhat more productive. Near the mouth of the Tennessee River the thick gravel deposits are well charged, and moderately large sustained yields are available from wells.

MINERAL QUALITY

Some mineralization of natural waters inevitably occurs as the water moves over the ground, along the stream channels, and beneath the ground surface. The type and amount of minerals in the water reflect the composition and the solubility of the rock materials with which the water has been in contact and the duration of this contact. Some mineralization also occurs from the various uses made of the water along its course.

Most unpolluted surface waters of the Valley do not contain objectionable concentrations of minerals. Silica is found in average concentrations under 10 parts per million which permits use of water for most purposes except high-pressure boiler feed water. Iron concentrations are generally under 0.1 part per million which is satisfactory for all except the bleaching and dyeing of textiles and in the paper industry. In the Valley these industries are concentrated in the Appalachian Mountain region where iron content is at a minimum. Magnesium, which is not critical for industry, is relatively low in the Valley waters. Sulphate, another uncritical mineralization, is found generally in concentrations under 10 parts per million except in the Clinch and Holston River basins. Chloride concentrations in the unpolluted streams are almost entirely in the range of 1 to 3 parts per million, far below industrial application tolerances. Scattered sampling for fluoride shows concentrations of about 0.1 part per million or less, well below the tolerances for food processing and carbonated beverage manufacture.

Hardness—Hardness is one of the most important characteristics of water as far as industrial and domestic uses are concerned. Water for high pressure boiler feed must be very soft, and soft water (50 parts per million or less of hardness) is required for some cooling purposes, food canning and processing, laundering, rayon and other textile manufacture, and steel manufacture. About one-half of the Valley is blessed with soft water. This includes all of the southeastern area and much of the extreme west. In the remaining half of the Valley, hard water (over 100 parts per million) is found only in the Central Basin portions of the Duck and Elk Rivers, along Paint Rock River in northern Alabama, along the North Fork Holston and Holston Rivers (due to pollution), and on several small streams in the eastern section.

WATER TEMPERATURES

Enormous volumes of water are needed for steam plant condensing water and industrial cooling water in the Valley. For these uses the temperature of the supply is sometimes a more important characteristic than its mineral quality.

Temperatures of the free-flowing, unregulated streams of the Valley follow closely the trend of air temperatures. During December, January, and February, temperatures range between 35 and 45 degrees F. After February the streams warm steadily to highs of 70 to 80 degrees in mid-June through August.

Effect of Reservoirs—Important differences from this pattern occur in the deep TVA tributary reservoirs. Near the surface the water temperature varies with the air temperature but at levels at and below the turbine intakes the water may remain below 50 degrees throughout the summer. This cool water near the bottom of the reservoirs supplies a substantial part of the water that is drawn through the turbines during the summer and fall months. Below Norris and Fontana Dams the river water temperatures rarely exceed 65 degrees. Below Douglas, Cherokee, and Hiwassee Dams the temperatures rise to 70 or 75 degrees but this peak is usually delayed until September. These cool clear waters flowing from the powerhouses during the summer have been particularly attractive to industries and steam plants that have established along the river banks.

TENNESSEE VALLEY RESERVOIR SYSTEM

The system of reservoirs that regulates the flow of the Tennessee River and its major tributaries is one of the largest in the world. Only two of the major tributaries, the Duck and Elk Rivers, are without regulatory projects. Figures 1 and 10 show the location of the reservoirs in the system.

Primary objectives of the TVA multiple-purpose dams are "to regulate the streamflow for the purposes of promoting navigation and controlling floods." As much hydroelectric power is produced as is consistent with attaining these priority purposes. Malaria control has necessarily become an important function of operation of the reservoirs for water control. There are other less important purposes whose requirements are coordinated with the comprehensive plan of operations as long as these do not infringe upon the major objectives.

Method of Operation

Important to other users of the reservoirs and regulated waters of the Valley is the method of reservoir operation adopted by TVA to accomplish its objectives. Figure 11 shows typical operation curves for a tributary and main river reservoir.

In the multiple-purpose reservoirs, this is an annual cyclical method which takes advantage of the seasonal runoff pattern in the Tennessee River and which permits the Authority to make double use of storage space for both flood control and power. It provides for (1) minimum reservoir levels affording the greatest flood storage space on or about January 1; (2) gradually rising levels until the end of March; (3) more rapid filling from that date until about May or June 1; and (4) a gradual drawdown for power production in summer and fall to reach the beginning of the cycle again on December 31. In this cycle the system is never left without flood storage where needed.

Actual levels reached in the multiple-purpose reservoirs in a given year depend upon streamflow conditions. Figure 11 shows the actual levels during 1957 at two typical reservoirs. If large floods occur in the January-March period the reservoirs may fluctuate considerably in these months, storing water during the floods and releasing it afterward. After the flood season is over, the amount of filling to summer levels will depend upon the April to June discharges of the inflowing rivers. The elevation of the reservoirs in the fall drawdown period will vary with the level reached in the summer and with the inflows in the fall. These variations in water surface elevation for a given time of the year may be as much as 40 or 50 feet from year to year in the tributary reservoirs. The nine main river reservoirs, which have less storage function, show less fluctuation.

Effect on Water Quantity--The storage of surplus waters in the reservoirs has two important effects on water quantities available to other users. The reservoirs themselves provide a very large supply of water to users along their shores. Already taking advantage of these supplies are large cities such as Chattanooga and Knoxville, huge steam plants, and many important industries.

In addition to this impounded water, the modification of streamflow below the large TVA dams by reservoir operation reduces flood flows and makes more water available during the low flow season. The degree to which this regulation is beneficial depends upon the storage available and the method of operating the generating units for the production of power, as well as on the nature of the needs for water downstream.

Effect on Water Quality--Storage of water for periods of time results in certain changes in the physical, bacteriological, biochemical, and mineral

FIGURE 10

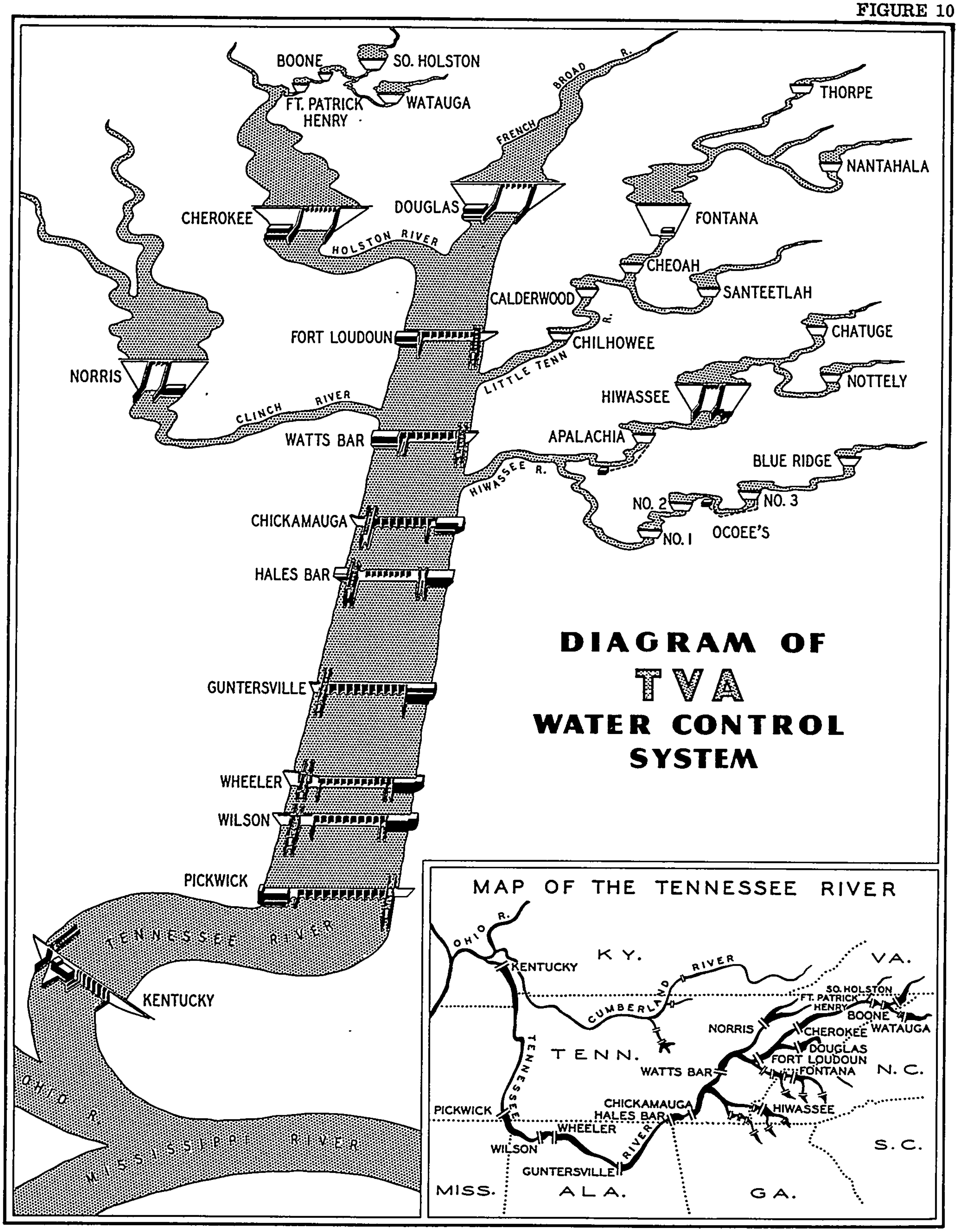
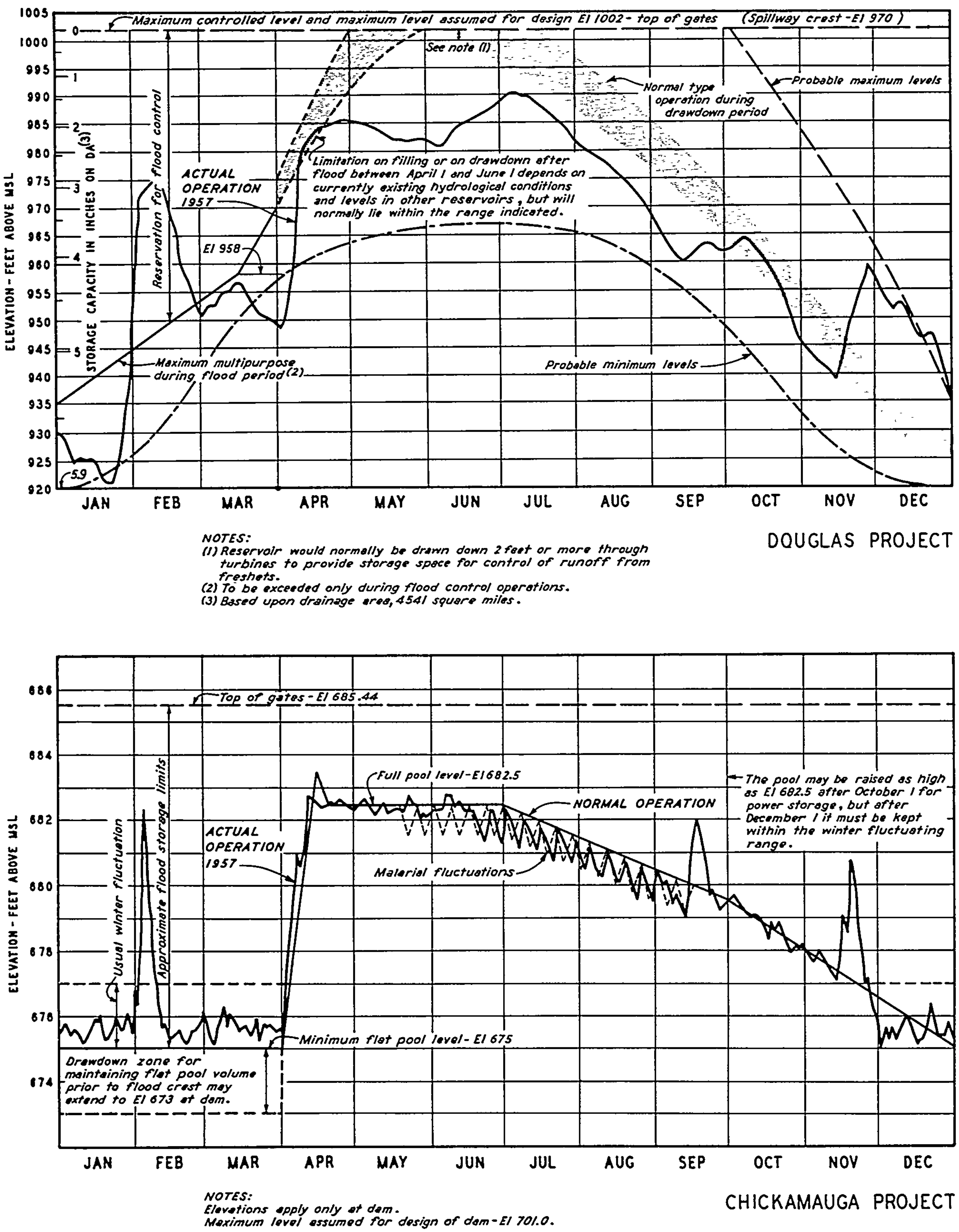


DIAGRAM OF
TVA
WATER CONTROL
SYSTEM
BOONE
SO. HOLSTON
FT. PATRICK HENRY
WATAUGA
FRENCH BROAD R.
THORPE
NANTAHALA
CHEROKEE
DOUGLAS
FONTANA
HOLSTON RIVER
CHEOAH
SANTEETLAH
CALDERWOOD
FORT LOUDOUN
CHILHOWEE
CHATUGE
LITTLE TENN R.
NORRIS
NOTTELY
CLINCH RIVER
HIWASSEE
WATTS BAR
APALACHIA
BLUE RIDGE
HIWASSEE R.
NO. 2
NO. 3
NO. 1
OCOEE'S
CHICKAMAUGA
HALES BAR
GUNTERSVILLE
WHEELER
WILSON
PICKWICK
TENNESSEE RIVER
KENTUCKY
OHIO R.
MISSISSIPPI RIVER
MAP OF THE TENNESSEE RIVER
OHIO R.
KENTUCKY
KY.
VA.
CUMBERLAND RIVER
SO. HOLSTON
FT. PATRICK HENRY
BOONE
WATAUGA
NORRIS
CHEROKEE
DOUGLAS
FORT LOUDOUN
FONTANA
TENN.
WATTS BAR
N. C.
TENNESSEE
CHICKAMAUGA
HALES BAR
HIWASSEE
PICKWICK
WHEELER
WILSON
RIVER
S. C.
GUNTERSVILLE
MISS.
ALA.
GA.

FIGURE 11



MULTIPLE-PURPOSE RESERVOIR OPERATION

quality of the water that is released to the river below the dams. Most of these changes are beneficial to downstream uses.

The effectiveness of reservoirs in settling out suspended sediment is well known. Already discussed is the beneficial effect upon water temperatures. Also, storage in large reservoirs such as Fontana has been found to reduce the color concentrations resulting from paper mill wastes.

One of the most striking effects on water quality brought about by impoundment is the destruction of enteric bacteria. These bacteria, found where streams have been used for the disposal of sewage, diminish in population with time of exposure to surface water environment. The long retention of water in such reservoirs as Douglas and Cherokee allows time for this die-away to near completion with the result that the outflow from these large reservoirs is greatly improved bacteriologically over that of the natural inflows.

Because of a rather complicated biochemical action, several of the tributary reservoirs in the system produce water late in the summer that is very low in the vital concentration of dissolved oxygen. Until this water is again reaerated by exposure to the air as it flows down the stream channels, it has less than normal capacity to absorb pollution.

The beneficial effects of a reservoir in smoothing out the fluctuations in water hardness are substantial. During the high-flow periods of winter and spring, the flow in the streams has a relatively low concentration of hardness because it has been in contact with the ground only a short time. Mineral concentrations are normally high in the summer and fall seasons when much of the flow comes from ground water. Since the reservoirs are largely filled with the softer water and this is released in the fall, the benefits in dilution of hardness to downstream users are obvious.

STREAM POLLUTION

The degree to which a use pollutes water is a relative thing, depending largely on the requirements of the next use to be made of the water. Water containing pollutants that one user could not tolerate might be perfectly satisfactory to another.

In the Tennessee Valley, the present degree of pollution of the water has its most significant effect on the establishment or expansion of municipal and industrial supplies. Other uses affected in order of importance are recreational and aesthetic uses, fish and wildlife, agricultural uses, power generation, navigation, and waste disposal. The users that often most seriously pollute the water are the municipalities and industries that discharge their wastes, untreated or only partially treated, into the streams.

Municipal Pollution

In 1950 the Tennessee Stream Pollution Study Commission listed 16 cities, all within the Valley portion of the state, that the Commission considered to be most critical because of the effect of their sewage discharges on public supplies downstream. The list included Chattanooga and Knoxville. None treated their sewage in 1950, although two small places used septic tanks. By 1958 all of these places had either completed primary or secondary treatment systems or had plants under construction. During the last five years more municipalities in the Valley have installed waste treatment facilities than in any previous five-year period. A number of other cities have treatment works under construction or in the final stages of planning, and the municipalities appear to be making good progress toward a reduction in this source of pollution.

Wastes From Pulp and Paper Mills

Of all the industrial wastes discharged to streams of the Valley, that from some of the pulp and paper mills is most noticeable. One part of the waste, lignin, gives the water a black color which, as it is diluted, changes to brown and then to tan. The discharged cooking chemicals, together with the ligneous waste, also result in unsightly bubble formation below points of turbulence.

Three mills in western North Carolina produce wastes of this type. Color from one plant near the headwaters of the French Broad River persists noticeably in that river to the mouth above Knoxville, 190 miles away. Another at Canton, North Carolina, turns the Pigeon River black or brown for 133 miles of its length. During low-flow periods in the summer, the streams below these mills are devoid of dissolved oxygen in long reaches and unpleasant odors are produced. Another mill at Sylva discharges wastes into Scott Creek and thence into Tuckasegee River. During low flows the river is discolored for 20 miles down to Bryson City and thence through Fontana Reservoir.

A similar and serious problem has long existed below a mill at Harriman, Tennessee, on the Emory River arm of Watts Bar Reservoir. Construction to abate this pollution is now under way. Other pulp and paper mills at Kingsport, Knoxville, and Calhoun, Tennessee, cause local discoloration.

Wastes from Chemical Plants

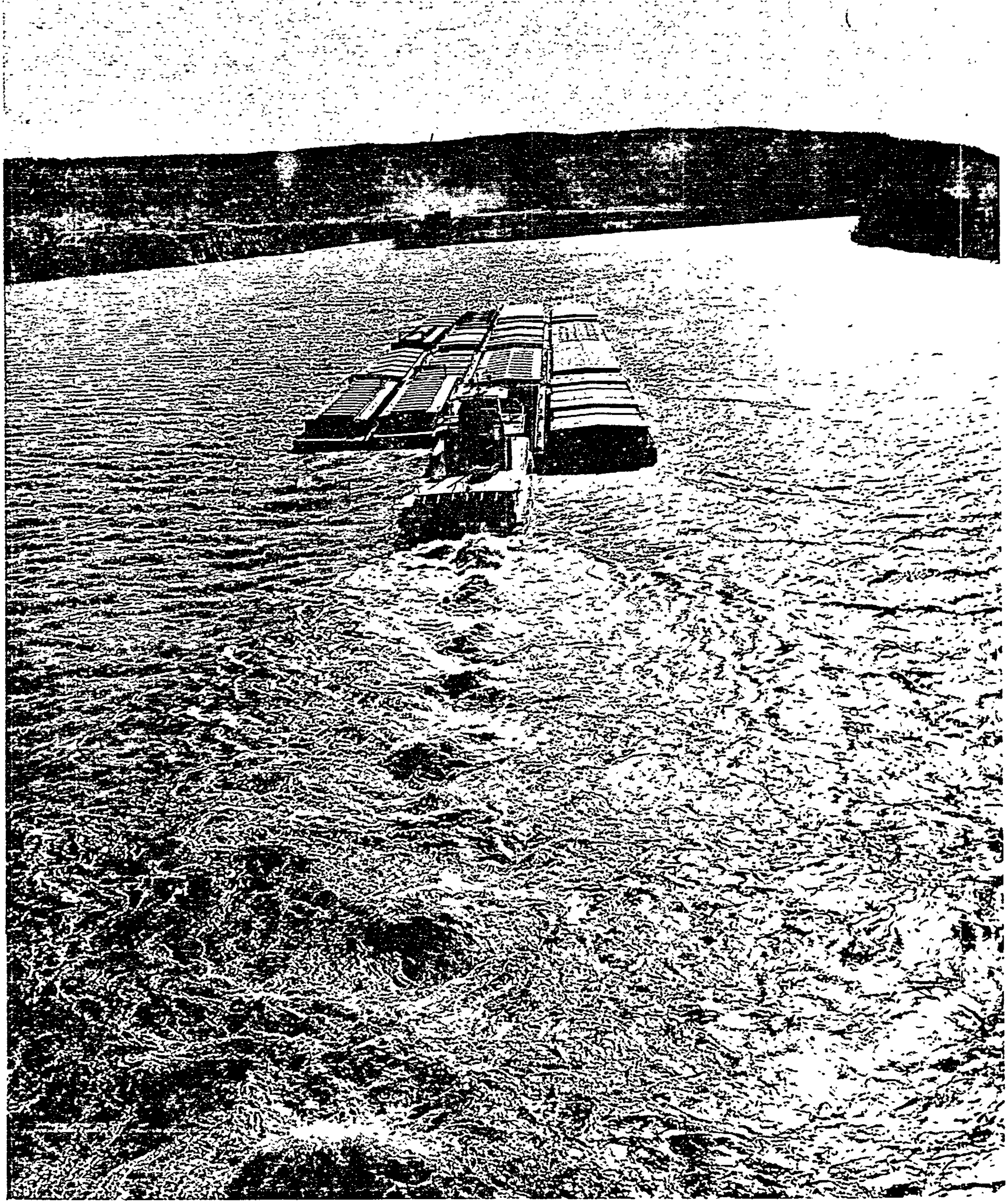
Perhaps the most serious pollution in the Valley from the standpoint of limiting other uses is that from a chemical plant on the North Fork Holston River at Saltville, Virginia. The discharge from this plant, containing calcium, sodium, and chloride ions, affects the North Fork Holston River, the Holston River and the Tennessee River for a total distance of 300 miles downstream. This pollution makes the water harder and more corrosive. Eighty-four miles of the North Fork are rendered useless as a source of supply for other industries. Even after mixing with the flow of the South Fork the water is unsuitable for many industrial uses. Occasional serious fish kills occur on the North Fork Holston River as a result of this chemical pollution.

Wastes from Rayon Plants

Wastes from two rayon plants at Elizabethton, Tennessee, deteriorate the water of the Watauga and South Fork Holston Rivers down to and below Kingsport. The principal pollutants have been copper, zinc, and ammonia. The two metals are toxic to aquatic life even in low concentrations. The ammonia is largely responsible for oxygen depletion in the lower portions of the Watauga arm of Boone Reservoir in the summer. Recently steps have been taken to reduce the rayon plant pollutants but no data are available on the effects of this reduction.

CHAPTER 4

WATER USES, PRESENT AND FUTURE



CHAPTER 4

WATER USES, PRESENT AND FUTURE

There are two major classes of use made of the precipitation that falls on the drainage basin of the Tennessee River. These are the natural uses, which man can control only locally and to a minor degree, and the social and economic uses which man, if he finds it necessary, can control to a high degree.

NATURAL USES OF WATER

The water used by nature in the growth of crops, forests, and other vegetation and in satisfying the demands of evaporation comes first in quantity and priority. In the Valley, nature takes an annual average of 29 inches from the 52 inches of precipitation. Part of this is evaporation from land surfaces, including leaf surfaces which intercept precipitation, and part is the moisture transpired by vegetation. The water that is transpired by farm crops and by merchantable trees constitutes a fully beneficial use. The water used by weeds and other non-crop vegetation is a loss to man in the sense that it might have been used in growing crops. However, this use is also beneficial to the extent that this vegetation holds and enriches the soil and delays runoff.

Living plants use huge quantities of water. Their cells remain literally bathed in water at all times. The distribution of many species of plants and trees is largely dependent on the water economy. The water requirement of different plants has been the subject of considerable study and estimates have been made ranging from 250 to 1,000 pounds of water for each pound of dry matter produced by the plant. The Valley foresters estimate that it takes about 700 pounds of water to produce one pound of solid plant material in the trees of this region.

Much of the available evidence indicates that, with equal meteorological conditions and under close vegetative cover, water is disposed of by plants with equal rapidity regardless of botanical composition. Percentage of cover thus becomes the most important factor in determining the rate of water use. The greatest total use of water from a given area, therefore, would be by the vegetation that has the best ground cover through the season and that has roots which remain active and within reach of moisture supplies.

As an example of the volume of water used by vegetation, TVA foresters estimate that in 1956 the 14,042,000 acres of forest in the Valley transpired approximately 22 inches of water in the growing season, or about 25.3 million acre-feet. Of this amount 17 inches came from rainfall in the growing season and 5 inches came from soil water stored during the winter.

CONTROLLABLE USES OF WATER

The residue from Nature's use, highly variable in time and place, provides the water for the second major class of use--that involved in the needs of municipalities, industry, irrigation, navigation, recreation, power, and other activities. It is this class of use, over which man can exert some degree of control, that must be fully understood to provide a sound basis for wise development and use.

Classification of Uses

In comparing volume of water used with available supply, a logical method of classification is essential. Some uses consume the water so that is is no longer available for other use. Some uses pollute the water so that its further use is limited to those uses which can tolerate the pollution. Some pollution is temporary, or self-correcting. Other pollution is permanent. To add together the volumes used without taking into account these limitations on further use would give an erroneous impression as to the surplus available for expanded or new uses.

The classification should also take into account any handling or manipulation of the water that is necessary to the various uses. In the classification proposed for this study the uses are grouped into three classes as far as the degree of manipulation is concerned. The Class A, or in place uses, are those requiring no withdrawal of the water from a natural channel, lake, or impoundment and no regulation or handling of the water specifically for the uses. There is no particular sense of timing or management of water levels or releases involved; the water is used as it exists.

The uses in Class B, or regulatory uses require that the water be impounded and regulated to provide specific reservoir levels or quantities of flow at specific times and places. These uses involve no consumption or deterioration of the water and the regulation is often beneficial to other uses.

The uses in Class C require the actual withdrawal of water from surface and ground-water sources. Some of these uses are quite consumptive; most of them involve a degree of deterioration of the water. For this reason they are the source of more conflicts than either of the other two classes.

The tabulation below outlines the classification adopted for this study. In the discussion that follows the uses are taken up in the order in which they appear in the table, except that the in place and regulatory aspects of the navigation use are discussed together.

TABLE 8

CLASSIFICATION OF WATER USES

Class and Use	Approximate Percentage Consumption	Degree of Deterioration[a]
A. In Place Uses		
Recreation and Fish and Wildlife	0	N
Navigation	0	N
Pollution dilution	0	M to S (T or P)
Drainage	0	N
B. Regulatory Uses		
Flood Control	0	N
Navigation (lockages)	0	N
Hydroelectric power	0	N
Mosquito Control	0	N
C. Withdrawal Uses		
Irrigation	90	N
Rural	50	M
Municipal	10	S (T)
Industrial (excluding steam plants)	5	S (T or P)
Steam power generation	0[b]	M (T)
Mining operations	25	M (T)

(a) Symbols -
- N - none or negligible
- M - moderate
- S - serious
- T - temporary
- P - permanent

(b) Cooling towers and ponds, which were not used until 1958 in the Tennessee Valley, would increase consumption.

IN PLACE USES

RECREATION AND FISH AND WILDLIFE

The Tennessee Valley is endowed by nature with recreation resources in unusual variety. It has the majestic scenery of the Great Smoky Mountains and the lesser ranges of the Southern Appalachians. Its forest cover is luxuriant. It has a proud history and an interesting culture. It is convenient in location to half the people of the United States. Ever since the Cherokee Indians roamed the Valley, its residents have considered hunting and fishing a favorite recreation.

The development of the Tennessee River added the one great recreational resource that the Valley had lacked--a chain of magnificent lakes. These lakes provide some 600,000 acres of water for swimming, boating, fishing, and water skiing. They offer 10,000 miles of shoreline for bank-fishing, waterfowl shooting, picnicking, camping, or just relaxing. Because of their size and distribution over the Valley, the TVA reservoirs are the principal source of water-based recreation in the Valley and this discussion refers largely to the situation on these lakes.

Characteristics of Use

Use of water for recreation and for fish and wildlife are in place uses which are non-consuming and non-polluting, except for the pollution resulting from floating craft sewage. The quantities of water used cannot be determined definitely, but they are very large. Quality requirements are variable but generally high. There is a definite seasonal variation in the use. Conflicts from other uses, particularly pollution dilution and the production of hydroelectric power, tend to limit full utilization of water for both purposes. In general the problems raised by these limitations are less serious than problems within the recreation field itself, such as water safety, conflict between such uses as fishing and water-skiing, and maintenance of adequate public access to the reservoirs.

Effect of Reservoir Operation

Recreation use of the tributary reservoirs as a group, even though these reservoirs have the greatest drawdown, is actually more intensive (in terms of use per acre of water or per mile of shoreline) than recreation use of the main-river reservoirs with less drawdown. Thus, operation of the TVA reservoirs for flood control and power does not appear to have measureably impaired their value for recreation or for fish and wildlife. Experience to date does not suggest a need to modify the over-all design or operation of the system in behalf of recreation or fish and wildlife interests. The mainstream reservoirs have attracted more intensive recreation development of their immediate shorelines than have the tributary lakes, but there is no evidence that they have contributed more to the over-all recreation development of the region than have the tributaries. In fact, the lack of commercial and private development on the immediate shorelines of the tributary reservoirs may make the reservoirs more attractive for recreation use in the future.

The needs of sport and commercial fishing and the wintering of migratory waterfowl are reasonably well satisfied by the present method of operating the TVA reservoirs. Possible exceptions are the release of water from storage dams at special times for the benefit of trout, and the modification of operations on occasions when the pollution hazard to fish requires it.

Winter Drawdown Benefits--It was at one time believed that permanent reservoir levels were essential to game fish production. Evidence collected on the TVA reservoirs, however, indicates that the proper water-level manipulation may actually furnish better fishing than permanent levels, at least in the Tennessee Valley region. The winter drawdown limits the abundance of bottom-feeding rough fish. Land vegetation which develops on the more gentle slopes during drawdown furnishes shelter for young fish and enriches the water locally through decay. Spawning is not greatly affected since the mainstream reservoirs are usually full and are held relatively constant at spawning time. On the tributary storage reservoirs the level is usually rising slowly at the time fish spawn. Close check is kept on water temperatures and operations are adjusted whenever possible to provide best conditions for spawning.

Extreme Drawdown--The effect of extreme drawdown is indicated by the experience on Douglas Reservoir which was completely emptied of stored water in January 1956. The following season the reservoir showed a greater production of sauger, white crappie, and rough fish and fewer large game fish than in previous years. The reservoir had many of the characteristics of a new reservoir. Norris, drawn almost as severely in 1956, showed a buildup of large-mouth bass over small-mouth and excellent reproduction of walleye and white crappie. Bluegill increased over the previous year. Most rough fish remained the same. The deep drawdown of these reservoirs, which some feared would destroy the fish population, apparently had no lasting effects.

Quality Requirements

The quality requirements of recreation waters vary with the particular use to which they are put but certain elements are common to all. The water should be clear and relatively unpolluted, without unpleasant odors, floating oils, greases, or scums, and with a minimum of natural debris. The shorelines should be clean, accessible, and free of mud flats. Marshy areas along a lake shore are not a drawback but actually have high recreation value as open space and wildlife habitat. Aesthetic considerations require varying degrees of privacy for many forms of recreation.

Natural bathing waters have the highest requirements. They must be free of (1) municipal sewage carrying harmful bacteria; (2) industrial wastes that may be toxic or unsightly; (3) animal pollution; and (4) biological growths which may result in parasitic infections or toxic algal blooms. Fishing waters require sufficient oxygen, proper fertility, and freedom from toxic substances. The boating use itself has the lowest requirements, but it is almost impossible to separate boating from fishing or swimming so that actually the highest requirement may govern all of the recreation uses.

TVA Lake Waters Satisfactory--The quality of water in most of the TVA reservoirs is generally satisfactory for a sound program of recreation use and development. Exceptions are Boone and Fort Patrick Henry Reservoirs where studies have showed a poor fish population and practically no reproduction of desirable sport fish as a result of municipal and industrial pollution. Existing stream sanitation programs on the other reservoirs seem adequate at least to maintain a satisfactory quality.

Extent of Present Use on TVA Lakes

Recreation use of the TVA reservoir system has increased at a rate of about 15 percent a year in the last ten years. The 1957 total recreation use of TVA reservoirs and their shorelines was an estimated 33 million person-days, about 3,300 for each mile of shoreline, or 55 for each acre of water surface. This use is about four times as intensive as recreation use of national parks and several times as intensive as that of national forests but is not so intensive as to interfere with desirable degrees of privacy.

Shoreline Development--Serving the water-based recreation activities in the Valley are Federal, state, and local parks, Federal and state wildlife management areas, public access areas, and various multipurpose use areas. On the shores of the TVA lakes there are 12 state parks and 55 city and county parks, some 350 commercially operated fishing camps, boat docks, and resorts, 40 camps operated by such agencies as the Boy Scouts, YMCA, and churches, and 63 private clubs. Nearly 5,000 individuals have acquired lakefront lots and have built summer homes.

Investment and Revenue--Total value of the recreational equipment and facilities on TVA lakes and shorelines in 1957 was about $72,000,000; about 70 percent was in shore-based facilities and the balance in boats and floating equipment.

In 1956 the gross revenue from shoreline recreation operation on TVA reservoirs was estimated at $6,900,000. These operations provided the equivalent of 1,400 man-years employment, with a payroll of about $1,400,000. The total expenditures generated by recreation use of the reservoirs in 1956 are estimated to be $75,000,000, or $50 for each Valley family. This is the equivalent of 15 percent of all recreation travel business in the Valley and one percent of all retail trade.

Picnicking

Boating

Swimming

Fishing

The TVA system of dams has provided a playground of 600,000 acres of water and 10,000 miles of shoreline. People such as these made up the 3.3 million person-day visits to the lakes estimated for 1957.

Fishing--Most recreation use of the TVA lakes has fishing as its origin. There is no closed season. In 1956 in Tennessee alone, 562,000 residents and 166,000 non-residents bought fishing licenses. Lake fishing naturally leads to boating. In 1957 some 35,000 pleasure boats were kept on TVA lakes during the season. Probably an equal number of boats was kept on trailers in yards and garages. Hundreds of thousands of people don bathing suits every warm weekend to swim and play in the lakes and in the cool mountain streams.

The number of individual, one-day fishing trips on TVA waters is estimated at more than 2 million a year. About 450,000 trips occur on tributary reservoirs, 890,000 on mainstream reservoirs, and 960,000 in tailwaters immediately below dams. The catch in all TVA waters, both sport and commercial, exceeds 10 million pounds a year.

Commercial Fishing--The commercial fish harvest for fiscal year 1957 in the northern Alabama reservoirs was the largest in years, totaling two and one-half million pounds of fish worth $464,000. The commercial catch on other TVA reservoirs added another two and one-third million pounds. Since 1943 the average net increase in the total catch per year has been about 125,000 pounds. The present harvest per acre is about 12.8 pounds.

Although there was a sharp decrease in the mussel shell harvest in calendar year 1956, some 6,600 tons produced represented 67 percent of all the fresh-water shells used by the United States button industry. Their value was about $391,000. The decrease from 11,000 tons in 1955 was apparently a result of heavy digging which has depleted the mussel beds. The end of the year saw a shift by musselmen upstream from Alabama reservoirs to Chickamauga Reservoir where mussels suitable to the button industry have been found.

Waterfowl--The waterfowl population on the TVA reservoirs in fiscal year 1957 was the highest since records were begun in 1935. Ducks totaled 425,000 and geese 37,000. The wintering population was 135,000 ducks, 26,000 geese and 800 coots. The Valley lakes have become an important link in the north-south flyway for these waterfowl, as well as a wintering ground. Many birds are being diverted from the nearby Mississippi flyway to the Valley lakes.

Some 31,000 acres of land were made available to other agencies by TVA for the production of waterfowl food. In 1940, only 1,400 acres were so planted. The area of land and water made available by TVA for use as Federal or state wildlife refuges or management areas totals 195,345 acres. Sixty-five percent, or 126,563 acres of this area is subject to permanent or periodic flooding.

Other Streams and Lakes--The emphasis on the TVA reservoir situation in this discussion is not intended to lessen the importance of the fishing streams of the Great Smoky Mountains and the National forests, or of lakes on state and private lands. However, because these streams and lakes are individually small and widely scattered it is difficult to isolate and measure their effect on the total situation.

Use in 1975

With more people moving from rural to metropolitan areas there will be more need for recreation outlets in 1975. The new interstate highway network will bring more vacationers through the Valley, and intensified advertising programs will cause a higher proportion to stop.

Growth in Use of Lakes--At the present rate of growth the use of the TVA lakes and shores for recreation will almost triple by 1975. User-days will grow from the present 30 million to 75 million. This is at the rate of 125 person-days per acre of water surface or 7,500 per mile of shoreline, assuming no increase in the present reservoir system.

There will be at least 10,000 vacation cottages along the lake shores and close to 800 commercially operated services and concessions. Some of the present simple fishing docks will grow to large resorts. Recreational investments generated in the Valley by the TVA reservoir system will increase to about $175,000,000.

Public Access Needed--Although the TVA reservoir system can support this anticipated growth, it will be at the price of some loss of privacy for individual users and a consequent lessening of certain aesthetic values. Some locations along the lakes are already over-crowded; others will become so. Public access areas will become an increasingly important means of satisfying the desire to get near or to the water. Maintaining adequate public access to the reservoirs and their shorelines is a major problem that will affect the continued growth and development of recreation on the system of lakes.

Many Fish Not Caught--Only a small percentage of the fish crop in the TVA lakes is harvested each year. Fish tagging, which has been carried out on a number of the reservoirs since 1945, has revealed that the fish crop in the lakes is not being over-harvested. The average harvest rate on game fish for all mainstream reservoirs is estimated at only 6.5 percent. This percentage has a general trend upward but even in heavily fished areas it is not likely that there will be any depletion of the fish crop. Actually the crop is not adequately harvested, and a large percentage is wasted. In these waters fish grow very rapidly and die young. Not many attain an age of five years.

Commercial Fishing to Grow--The change to be expected in commercial fishing depends on such factors as the availability of higher paying employment for men now engaged in commercial fishing; regulation of fishing, now in a state of flux; demand for low cost protein food; market development, and availability of fish. If commercial fishing continues to grow as in the past 15 years, the 1975 catch would be about 4.5 to 5 million pounds, worth about one million dollars at present prices.

The prospects for mussel shell harvesting in 1975 are very uncertain. There is evidence that recent spawning is not adequate to produce a sustained annual yield of this resource.

POLLUTION DILUTION

The dilution of pollution by the flow of streams in the Tennessee Valley is an in-place use of water which involves the discharge of sewage and wastes from cities and industries, with or without treatment, into the streams with the expectation that certain natural assimilative processes will take place. There is no definite quantitative answer to the question of how much stream dilution of a raw or partially treated waste is required to render it unobjectionable. Only relative values are possible, and these are largely a matter of opinion except where a pollution control agency has assigned numerical values as limits of pollutants. In situations where streamflow regulation is an important factor, TVA cooperates with the control agencies in planning pollution control measures.

Population Equivalent

As a common denominator, industrial as well as municipal wastes of an organic character can be expressed in terms of population equivalents. Thus, a given industrial waste can be said to require as much dissolved oxygen in its stabilization as would the domestic sewage from a certain number of people.

This term can be used only in reference to organic wastes and not to wastes of a toxic or mineral nature, or to wastes producing such effects as color or heat.

Dilution Process, Organic Loads

Streams assimilate organic loads by supplying through biochemical processes the oxygen demanded by the decomposable material from the supply of oxygen dissolved in the water. Experience in many locations supports the rule-of-thumb assumption that streamflow of one cubic foot per second in the warm season of the year can absorb an organic pollution load equivalent in strength to the raw sewage contributed by 100 people without producing objectionable conditions downstream. To determine the dilution capacity of an unregulated stream, this criterion is usually applied to the lowest seven-day average flow that occurs once in ten years.

Where coliform bacteria are involved these methods do not apply. To reduce the coliform concentrations in a sewage-polluted stream to the level that could be satisfactorily purified in a modern water treatment plant downstream, several hundred times the dilution needed for organic load would be required. Where bacteria concentrations are of real concern, chlorine is used as a bactericide.

Dilution of Industrial Wastes

The amount of dilution necessary for untreated industrial wastes depends upon the downstream use or uses to be protected. Most of the natural purification processes that occur in a stream to reduce the objectionable characteristics of sewage pollution are not effective in reducing concentrations of many toxic and chemical wastes. Some industrial processes result in wastes that are virtually untreatable from an economic standpoint and under the present state of technological development. These industries must depend upon dilution as the only available technique of waste disposal, and it is advantageous for them to locate on the largest stream available. This is true also of plants with treatable wastes. Since the expenses of waste treatment are reflected in the final cost of production, the plant that is located on a large stream can sell at a lower price or make a larger profit, all other factors of competition being equal. Also, by locating on the large streams the tributary streams are kept clean as sources of industrial water supply.

Waste Treatment

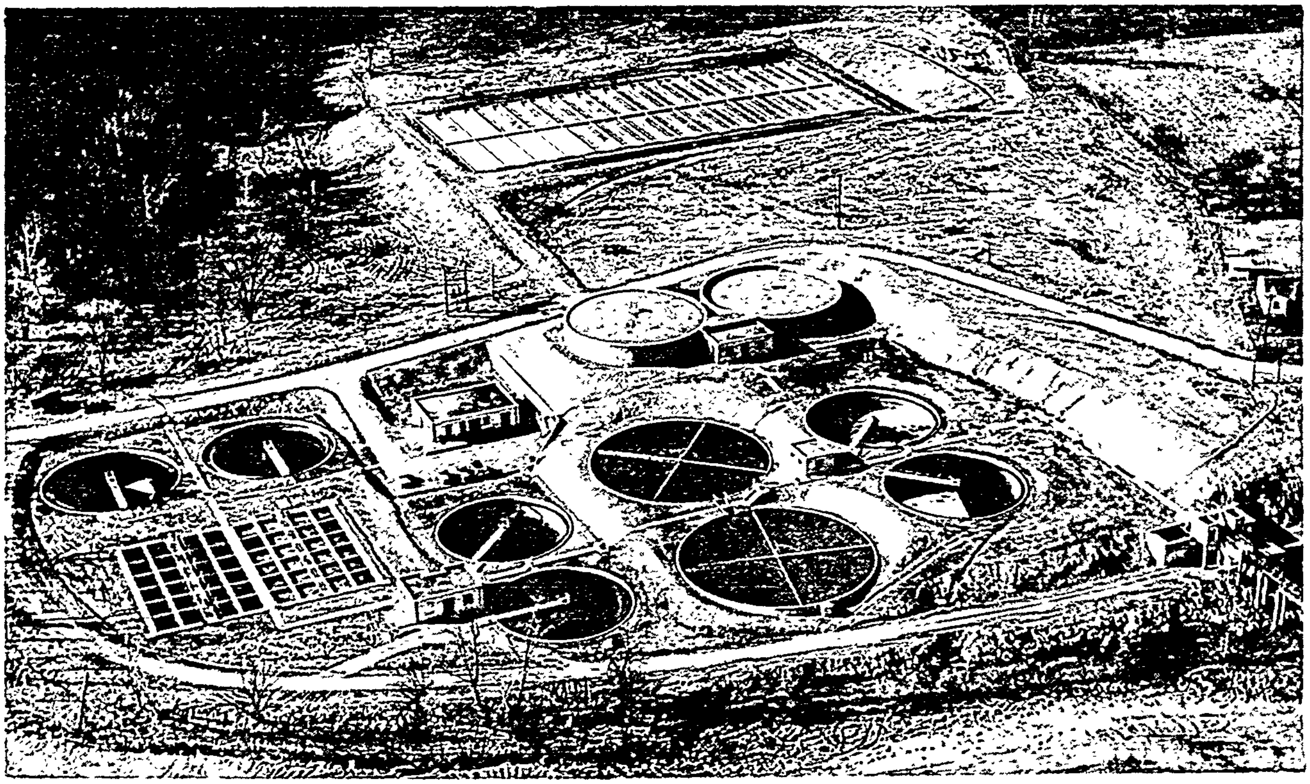
Treatment of wastes by cities or by industries is normally provided only to the extent required by law or to avoid complaints from downstream water users. Cities build sewage treatment plants that are able to provide, in a restricted space on land, the purification that nature would require days of time and many miles of flow in a stream to provide. A primary treatment plant reduces the organic polluting strength of sewage by about one-third. A secondary plant includes additional biological treatment processes that remove 90 to 95 percent of the biological oxygen demand, 85 to 95 percent of the suspended solids and, with chlorination, 98 to 99 percent of the bacteria.

A number of treatment processes are used by industry. Among these are (1) reduction of waste volume, (2) modernization of processes, (3) reclamation as by-products, (4) lagooning, (5) biological oxidation, (6) ion exchange, and (7) disposal to municipal systems.

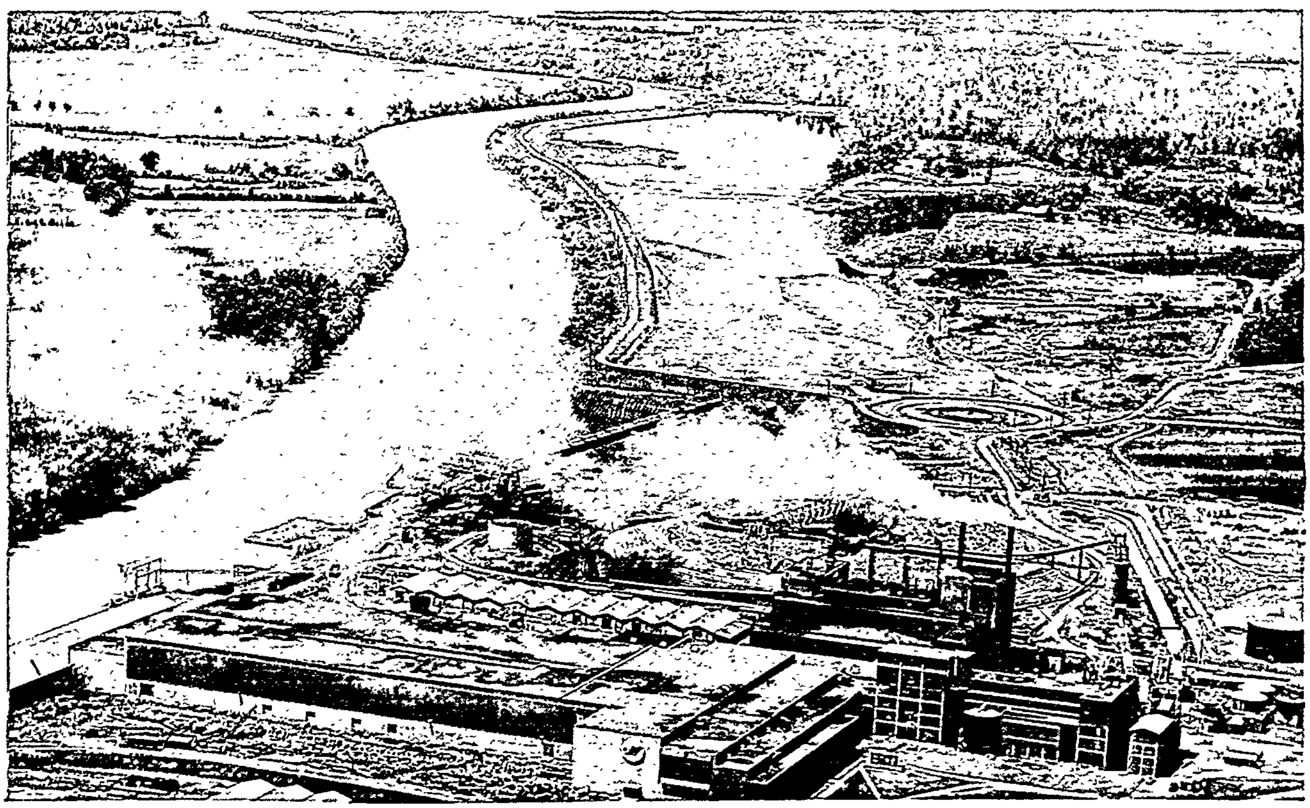
Present and Future Use of Water for Pollution Dilution

It is not possible to estimate what volume of the streamflow of the Tennessee River Basin is being used for the dilution of sewage and industrial waste. Portions of all of the larger streams of the Valley are in use for this purpose as are many of the smaller streams. The municipal sewage load alone is substantial, although far less than the industrial load. Table 4 shows for each of ten major subdivisions of the Valley the present (1955) population connected to municipal sewer systems and the population equivalent that these systems discharge into the streams after sewage treatment. The latter figure is determined on the basis of a one-third reduction for all primary treatment plants and a 90 percent reduction for all systems with secondary treatment.

It is expected that by 1975, all of the municipalities included in the 1955 list would place in operation either primary or secondary treatment plants. Thus even though the connected population is expected to increase 20 percent by 1975, the population equivalent of discharged sewage will be only 72 percent of that in 1955.



Cities build sewage treatment plants to control pollution.



Large industries such as this paper mill may lagoon their wastes.

TABLE 4

POPULATION CONNECTED TO MUNICIPAL SEWAGE COLLECTOR SYSTEMS AND POPULATION EQUIVALENT OF SEWAGE DISCHARGED TO STREAMS AS OF 1955 AND PREDICTED FOR 1975

Drainage Basin[a]	Connected Population		Population Equivalent Discharged to Stream[b]	
	Present 1955	Predicted 1975	Present 1955	Predicted 1975
Tennessee River, mouth to Pickwick Dam	39,100	52,500	16,300	9,000
Duck River	52,200	67,300	32,500	8,400
Tennessee River, Pickwick to Guntersville Dam	139,100	200,200	122,100	62,600
Elk River	29,000	39,200	15,700	8,600
Tennessee River, Guntersville Dam to Knoxville	402,200	583,900	284,200	315,800
Sequatchie & Emory Rivers	12,500	16,300	11,500	8,300
Hiwassee & Little Tennessee Rivers	49,500	61,700	26,900	16,000
Clinch River	78,900	98,300	56,100	18,500
Holston River	178,800	241,600	100,500	94,200
French Broad River	147,300	180,500	135,300	33,500
Total Tennessee Valley	1,128,600	1,541,500	801,100	574,900

(a) See figure 6 for location.

(b) After present (1955) treatment or predicted (1975) sewage treatment.

These municipal sewage discharges, which include those of industries tied into the municipal systems, are only about one-third as much as the population equivalent of pollution now being discharged directly to the streams by large industries in the Valley. One industry in the French Broad River basin in 1955 discharged waste equivalent to sewage from a population of 624,000. Industrial wastes in the French Broad River basin exceeded in 1955 the municipal sewage discharge for the whole Tennessee Valley. The industrial waste load in the Holston River basin is the second highest in the Valley and that in the Tennessee River drainage from Guntersville Dam to Knoxville ranks third.

State and local governments in the Tennessee Valley region have made great strides in the control of municipal pollution and are making good progress in reducing industrial pollution. Positive and vigorous action in the future is called for. Carefully designed preventive measures (usually more widely acceptable and economical than corrective measures) are needed to safeguard public health and provide for municipal and industrial growth. All of the Valley states now have stream pollution control laws, and presumably there will be continued pressures on present industry to reduce pollution and on new industry to install treatment measures. An interstate compact for control of stream pollution in the Tennessee Valley has recently been made a legal entity. The compact was approved by the Tennessee Legislature in 1955; Mississippi joined the compact in 1956, and Kentucky ratified it in August 1958. The consent and approval of Congress was given to the compact, and it became Public Law 734 of the 85th Congress on August 23, 1958.

DRAINAGE

There is some question whether drainage can properly be classed as a use of water. Some classifications list it; others ignore it. Although considerable drainage work has been carried out in the Tennessee Valley in the past, it is not presently an important water use. Generally intended to be beneficial, it may be in conflict in some respects with the providing of suitable habitats for fish and wildlife.

Purpose of Drainage

Drainage work in the Valley has been carried on principally in the Tennessee portion and mostly in the western part of that state. The 1940 U. S. Census report on "Drainage of Agricultural Lands" shows that, of 1508 miles of drainage district ditches in Tennessee, about 60 percent were for protection against overflow, 10 percent for reclamation of swamp land not previously farmed, and 30 percent for improvement of land in farms. This proportion of purposes is probably typical for most drainage work in the Valley.

Extent of Ditches

Valley maps show about 3,500 miles of streams which are labeled as drainage canals or drainage ditches or which appear, from their straight or regular alignment, to fall into this category. Nearly one-third of this mileage is on tributaries of Kentucky Reservoir and of the Tennessee River below Kentucky Dam. Two-thirds of the mileage is below Guntersville Dam. Most of the ditches in the Guntersville-Wheeler reach are on the north side of the main river while those in the Pickwick-Kentucky reach are on the west side.

Drainage Districts

A study of the history of 19 legally organized drainage districts in the Kentucky Reservoir area shows that 17 were organized between 1913 and 1922; one, an extension of an older district, was organized in 1934; and one, a WPA project, was set up in 1937. A Tennessee Act of 1909 authorized such districts.

Bonds were sold, ranging in total amount from $3,400 to $379,000. Assessments were made on the property benefited and the ditches were dug within two or three years.

In 1938 nearly all of these districts had some bonds still outstanding and considerable sums in taxes were delinquent. Little or no maintenance work had been done since the first few years, and the ditches were in generally bad condition. Little has been done since 1938. While there are exceptions, this history of agricultural drainage in the western part of the Valley is typical of that throughout the Valley.

Use in 1975

Whether or not drainage will be revived in the Valley as an agricultural practice depends on the prospect for generally improved farm management and on the coordination of drainage with related means for controlling damaging overflows on small streams. Public Law 566, as amended in 1956, authorizes drainage, irrigation, water supply, and other purposes in addition to the basic program of flood control on watersheds not exceeding 250,000 acres in extent. The amended law limits the Federal share of the costs allocated to drainage to 45 percent of the total drainage cost. This puts a rather heavy burden on non-Federal interests and private owners and has tended to cause local resistance or lack of interest in this aspect of the over-all program. TVA and other agencies have encouraged several cooperative projects to demonstrate the value of channel clearing and maintenance in reducing flood levels, but there has been no concerted effort on the part of local landowners to continue these projects.

REGULATORY USES

FLOOD CONTROL

The purpose of flood control by reservoirs is to store or detain destructive floodwaters so as to minimize physical damage and loss of life and thus permit fullest reasonable use of flood plain lands. The principle is simple; the practice, in a system as large as that of TVA, is an extremely exacting and complex operation. Since the reduction of flood heights in the Valley is now largely a TVA responsibility, this discussion is limited to TVA operations.

Characteristics of Use--Flood control by means of reservoir storage is a non-consuming, non-polluting, regulatory use of water. In the TVA system, where flood control is one of the primary obligations, the operation of reservoirs to ensure adequate storage space throughout the flood season results in some conflict with hydro power production, with recreation uses, and with other water uses that may be benefited by high and constant reservoir levels and maximum storage of water.

The TVA system is planned, in accordance with the Act, to provide control of floods in the Tennessee River and Mississippi River valleys. While not all communities and areas are fully protected, the system provides substantial flood reduction in critical locations and makes possible more complete protection in some areas by local works.

TVA Flood Storage Reservation

The TVA system of reservoirs includes 18 multiple-purpose projects. Ten of these are on the major tributaries and eight are on the main river. Storages reserved for flood control in these reservoirs at critical seasons of the year are given in table 5.

TABLE 5

STORAGE RESERVED FOR FLOOD CONTROL IN TVA SYSTEM

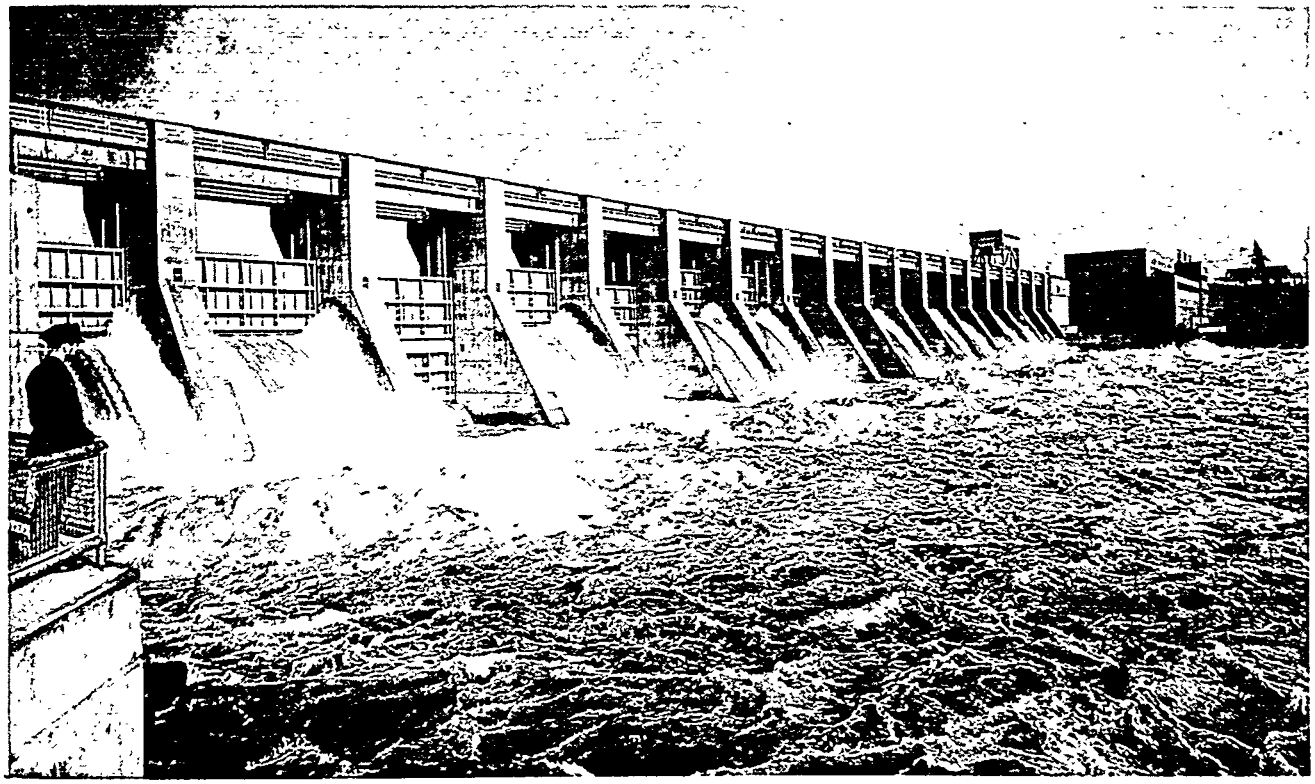
	Eight Main River Reservoirs	Ten Tributary Reservoirs	Total System
Net drainage area, square miles	26,780	13,420	40,200
Flood control storage, January 1			
In acre-feet[(a)]	5,808,900	6,005,300	11,814,200
In inches[(b)]	4.07	8.39	5.51
Flood control storage, March 15			
In acre-feet	5,808,900	4,604,500	10,413,400
In inches	4.07	6.43	4.86
Flood control storage, summer			
In acre-feet	1,582,000	903,200	2,485,200
In inches	1.11	1.26	1.16

(a) Level pool storage between normal maximum elevation and seasonal elevation.

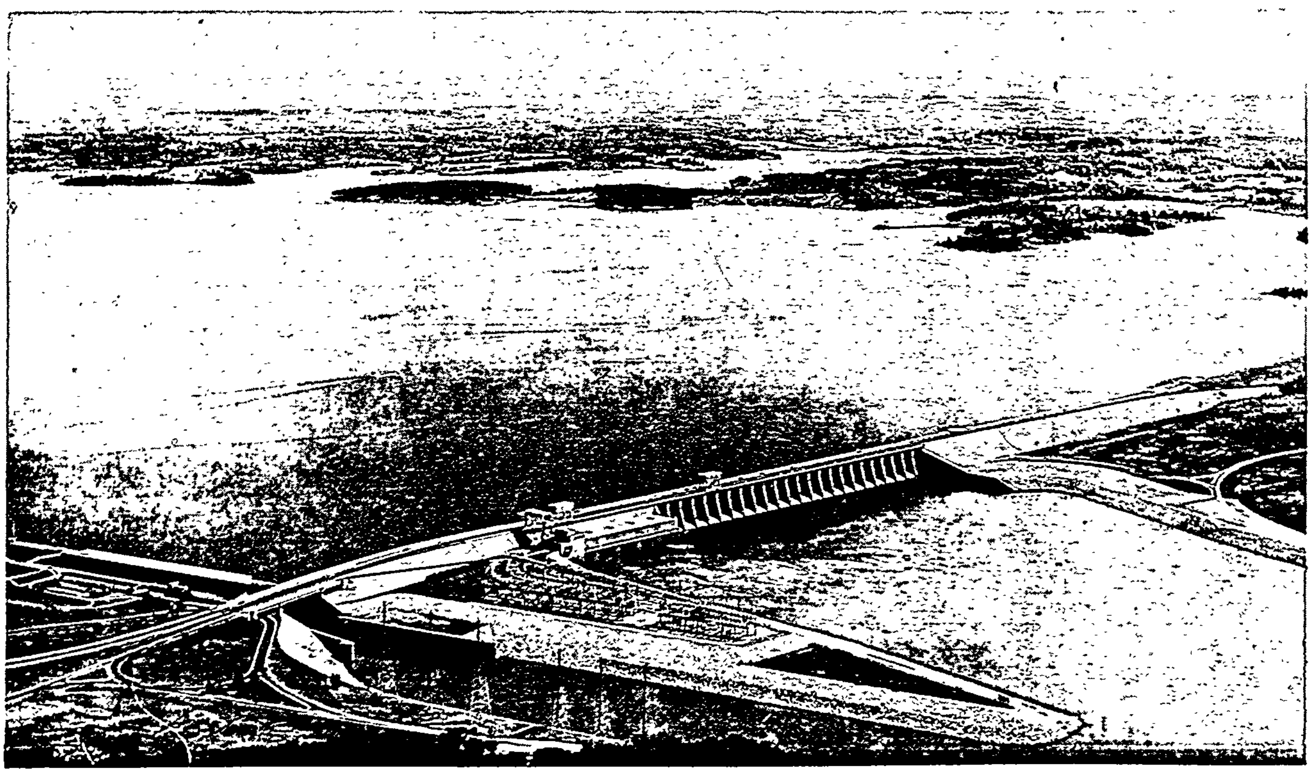
(b) Equivalent depth in inches over net drainage area.

The flood control storage above Chattanooga on January 1 and March 15 includes all of the reserved storage in the tributary reservoirs plus 816,000 acre-feet in Chickamauga, Watts Bar, and Fort Loudoun Reservoirs. The summer level reservation in the latter three reservoirs is 302,000 acre-feet.

Chattanooga is one of the focal points of TVA flood control operations. Prior to the establishment of TVA, Chattanooga had one of the most serious urban flood problems in the United States. Urban flood problems existed also at Elizabethton, Kingsport, and Knoxville. Equal in importance in planning the TVA system was the flooding of extensive agricultural lands and urban areas on the lower Ohio and Mississippi Rivers.



Ten tributary projects and three mainriver projects, including Chickamauga (above), control floods on the Tennessee River at Chattanooga.



Final regulation of Tennessee River floods is made at Kentucky Dam.

Cyclical Reservoir Operation

The long-term record of flood experience on the Tennessee River shows that Valley-wide destructive floods occur in a well-defined season from about the middle of December to the middle of April. In the eastern half of the Valley, substantial areas also have experienced devastating floods in other months of the year and especially in the hurricane season, but these are limited generally to the headwater portions of the French Broad, Little Tennessee, and Hiwassee Rivers and do not produce significant floods at and below Chattanooga.

This seasonal characteristic of Valley-wide floods led to the adoption of the annual cyclical plan of reservoir operation previously shown in figure 11. The Douglas Project operation is typical of tributary multiple-purpose operations while the Chickamauga Project operation is typical of that on a mainriver reservoir. The heavy line on the two parts of the chart shows actual reservoir operation for the control of floods in February, September, and November of 1957.

Elements of Operation--Principal flood control elements of the reservoir operations are the following:

1. Flood season, mid-December to April--This is the period of maximum flood storage. Mainriver reservoirs are held low except during flood control operations. Tributary reservoirs are allowed to fill somewhat as the danger of flood recurrence decreases.

2. Summer season--Beginning in April the reservoirs are filled as flows permit, but to guard against summer floods a storage reservation is retained in the top layer of the reservoirs. In terms of the net drainage basin this reservation is largest in Kentucky, Norris, South Holston, and Watauga Reservoirs.

3. Drawdown period--Reservoirs are drawn down, usually through the turbines, to reach flood season levels near the end of the year. This operation is generally compatible with best use of water for power generation but may require spilling of water on rare occasions if November and December flows are higher than turbine capacity. The drawdown operation to prepare for the coming flood season is as essential in the subsequent reduction of floods as the proper operation of the reservoirs during a flood.

Water Used in Flood Control

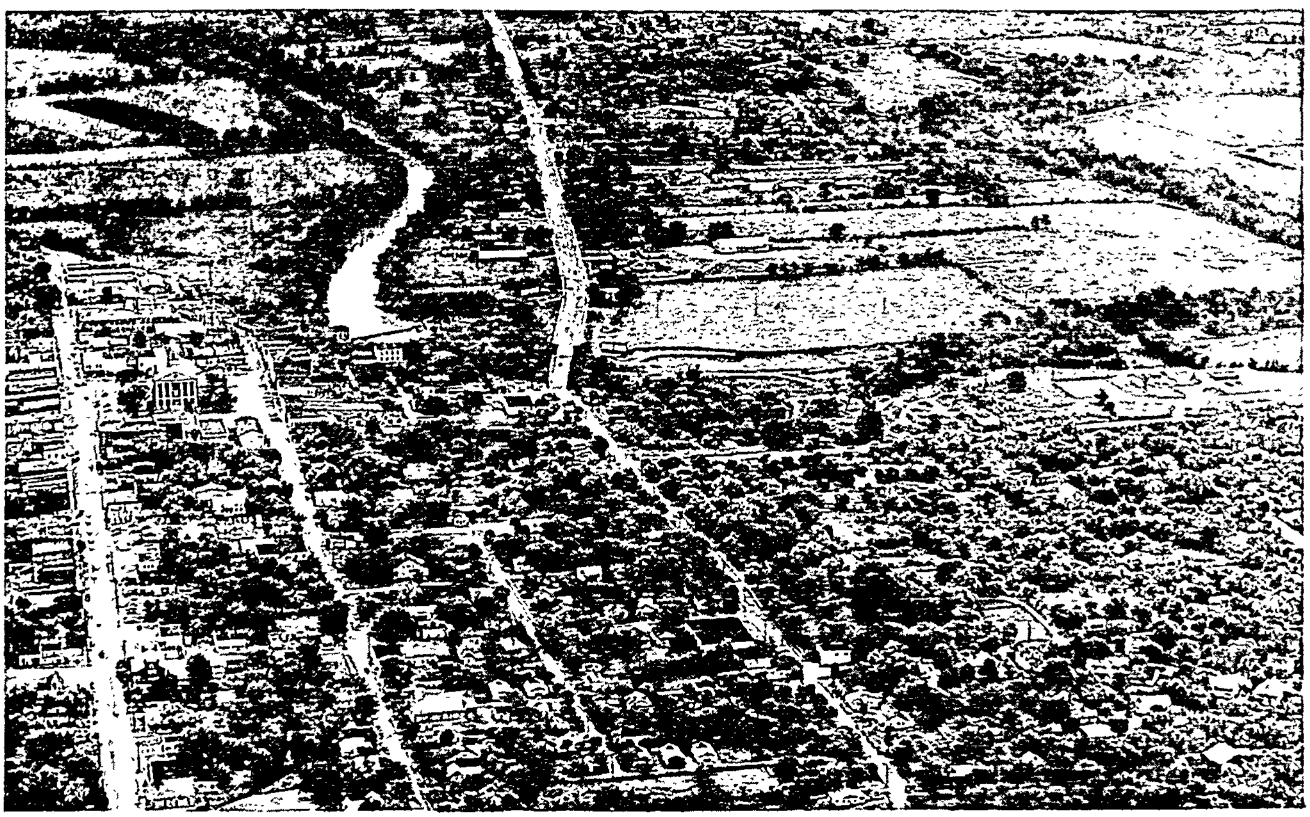
Two years in the last 21 stand out as examples in the use of the TVA reservoir system for flood control. In February 1950 the greatest use was made of Kentucky Reservoir and the system as a whole, principally to effect a significant reduction in Ohio River flood heights at Cairo, Illinois. In February 1957 the greatest use was made of the ten tributary reservoirs in reducing what would have been the second highest known flood at Chattanooga to a level barely over flood stage. In carrying out the 1950 flood control operation, 49 percent or 5.5 million acre-feet of the total storage space available at the time of the flood was filled. Nearly two-thirds of the mainriver storage and slightly over one-third of the available tributary storage was used. In 1957, about 43 percent of the available tributary storage was utilized and only 19 percent of the mainriver storage. Total use of available storage was 32 percent for the whole system.

The TVA system is designed and operated to provide the greatest feasible amount of reservoir storage for control of the great floods that can occur. The percentages of available flood storage actually used in controlling the 1950 and 1957 floods show that neither flood overtaxed the system, even though the control of these floods has represented maximum experienced use of the mainriver and tributary storage, respectively. Studies of the meteorology and hydrology of the region show that much greater floods than these are possible which may require all of the available storage.

Flood Control Use in 1975

The possibility of adding large volumes of multiple-purpose storage to the TVA system by 1975 appears limited. Three of four projects being considered for possible future construction include some flood control storage. One of these is on the Hiwassee River, one on the Little Tennessee River, and one in the Emory River basin. The completion of Barkley Dam on the Cumberland River and of the canal connecting Barkley with Kentucky Reservoir will improve the control of flood discharges from the two rivers to the Ohio and Mississippi Rivers.

During February 1948 flood.



Under normal conditions.

Many communities in the Valley are located on streams having no flood control. This is Shelbyville, Tennessee, on the Duck River.

<u>Chattanooga Situation</u>--Although the flood hazard has been largely eliminated by the TVA dams at some locations, there are others below the reservoirs where supplemental protective works are needed if complete protection against the maximum probable flood is to be attained. The most important of these is Chattanooga. Full protection of this city requires the construction of a levee system such as both the TVA and the Corps of Engineers recommended a number of years ago. With the degree of reservoir regulation now available such a levee system can be fully effective. This levee system, supplementing the regulation provided by the TVA reservoirs, would protect the city from a flood 60 percent greater than the maximum of record, the flood of March 1867. However, the city has failed to acquire the necessary land, and the Congressional authorization to construct the levees lapsed several years ago.

<u>Flood Protection Works</u>--The TVA has studied the feasibility of flood protection works for several locations in the Valley. One of these was for the upper French Broad River area, including Asheville, which involved a system of seven detention-type reservoirs, together with channel improvements and levees. Neither this or other such projects have been built.

<u>Local Flood Problems</u>--A large number of communities in the Valley, most of them located on smaller streams upstream from the TVA reservoirs or on streams having no control, are not now protected against floods. In connection with its local flood relations program, TVA has investigated the flood situation at about 40 of these locations at the request of the local and state planning bodies and has supplied these local communities with basic data on past floods and the magnitude of still larger floods which may reasonably be expected. With this information the communities are in a position to recognize their flood problems and to consider ways and means for reducing flood damages in the future, either through protective works, land use regulations, or a combination of these measures.

NAVIGATION

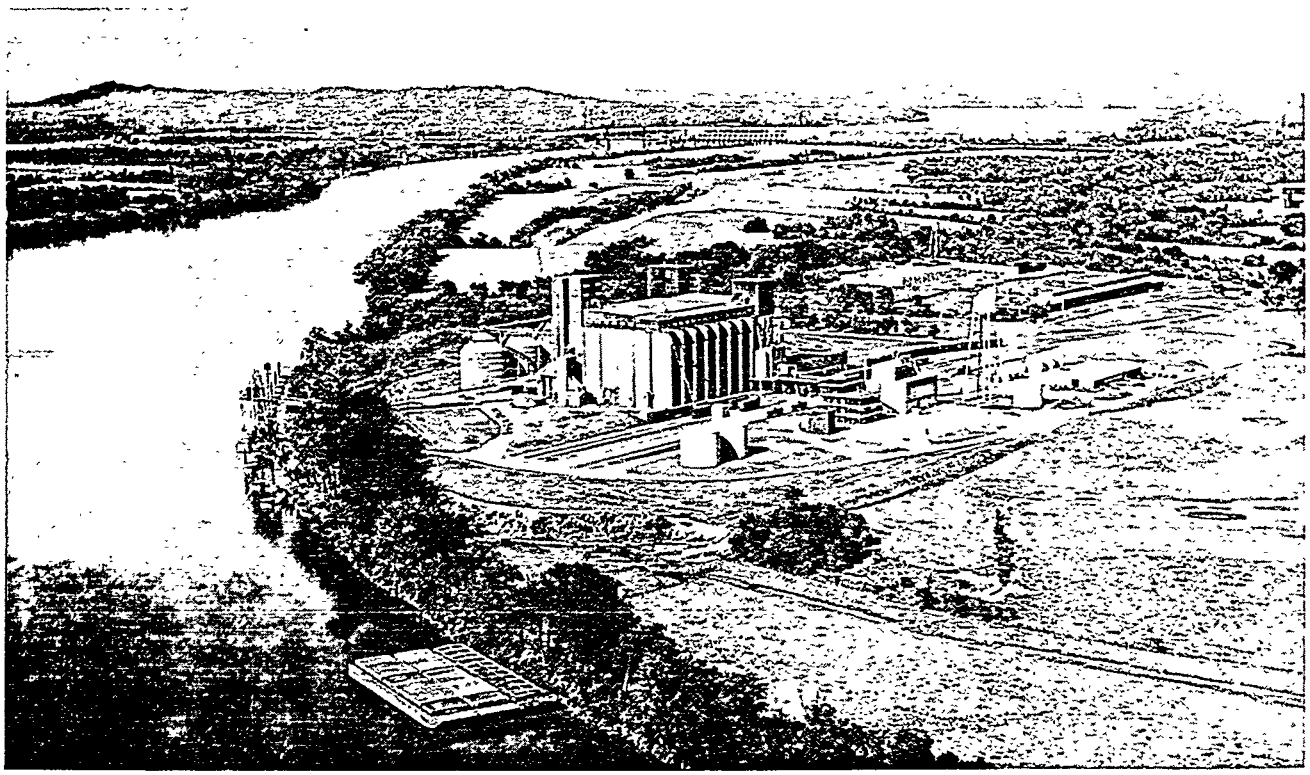
Navigation, for the purposes of this study, is limited to commercial navigation on the chain of TVA lakes from Knoxville to Paducah, including the major tributary portions of these lakes. In this sense, navigation involves two classes of uses: the use of water in place to provide a channel nine feet deep throughout the length of the Tennessee River, and the regulatory use necessary to provide lockages from reservoir to reservoir. Both aspects of the use are non-consuming and non-deteriorating and have no special requirements as to quality of water. Conflicts with other uses are negligible. Navigation on the lower Ohio and Mississippi Rivers also benefits from Tennessee River regulation through improvement of dependable minimum flow.

Growth in Navigation

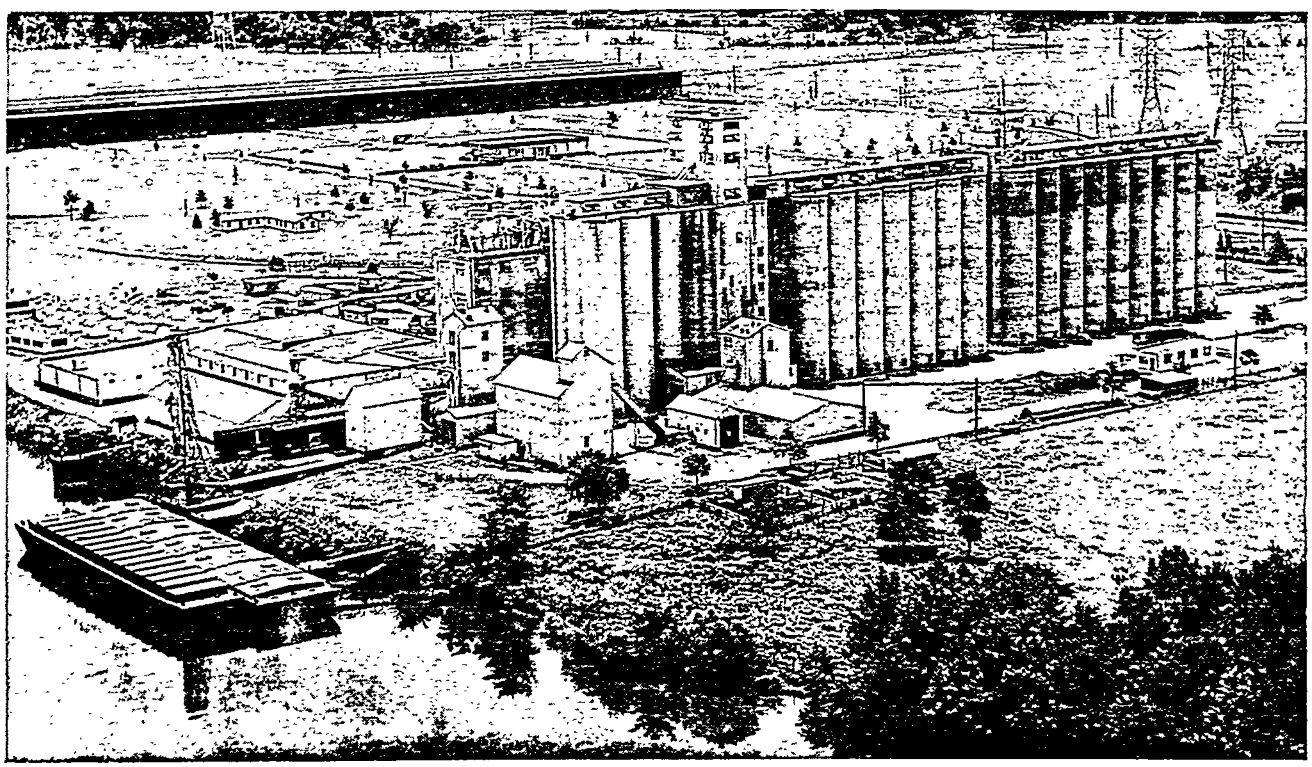
The improvement of the river channel following the construction of the TVA dams, the establishment of terminal facilities, the technological advances in barge line equipment and techniques, and the extraordinary expansion of industry in the Valley have combined to produce a significant growth in commercial river traffic. In 1933 the Tennessee River traffic was just under one million tons. In 1957 it was 12.7 million tons. The ton-mileage, a more accurate measure of the use made of the river, rose from 32.7 million ton-miles in 1933 to 2.1 billion ton-miles in 1957. To the sand, gravel, and forest products movements of the early years has been added new high-value commodity traffic such as petroleum products, automobiles, grain, soybeans, fertilizer, coal, coke, iron and steel articles, ferroalloys, scrap metals, salt, sulphur, asphalt, molasses, and chemical products. The average length of haul on the Tennessee River has increased from 35 miles in 1933 to 165 miles in 1957.

Water Requirements for Navigable Channel

The nine dams on the Tennessee River provide wide channels of adequate depth, low velocities, and pool levels that are remarkably stable except during the infrequent large floods. Certain criteria have been set up governing



Central Soya Company plant near Chattanooga, Tennessee.



Alabama Flour Mills, Decatur, Alabama.

Many industries which have been established along the Tennessee River make use of river transportation.

the regulation of flows to maintain minimum navigation pool levels, and the rates at which streamflows may be increased or decreased below the dams during high flows. These criteria occasionally have some limiting effect on other water use but, in general, it is not necessary to depend on a steadily maintained streamflow of substantial proportions to provide adequate depth, width, or other desirable navigation channel requirements.

Water Use for Lockages in 1957

Thousands of lockages are made through the mainriver dams each year for the movement of commercial traffic and pleasure boats. In 1957 the number of times the locks were emptied ranged from 1,200 at Fort Loudoun to 5,300 at Wilson Dam. Seasonal variations occur, with a significantly greater use of the locks in the summer months than in the winter. Part of this difference results from the movement of pleasure craft during the warm months. Lockage activity in the Hales Bar to Wilson reach is substantially greater than in the upper or lower portions of the river. To handle this heavy use, a new and much larger lock is now under construction at Wilson Dam for completion in 1959. This lock will be 110 feet wide by 600 feet long and will have a 100-foot maximum lift.

Water Re-used Often--Water used for lockages is a diversion from power generation except when a surplus is available. Otherwise this use is not a consumptive or wasting use but is merely a transferral of the place of use. Water supplied at Fort Loudoun Dam for lockages may be re-used many times on its journey to the river mouth at Paducah. The scheduling of releases to accommodate lockages at one dam probably does not exactly meet the scheduling of lockages at the next dam downstream. However, the daily requirements of lockage water are so small that they have no measurable effect on the large mainriver reservoirs. Irregularities tend to balance out. Excess lockage water not immediately used at the downstream dam is temporarily stored or used for power production except during floods when water is being spilled. In flood times the necessary wastage of water cannot be regarded as a debit either to navigation or power.

From this reasoning it is evident that the annual volume of water at the lock using the greatest amount in a given year represents the volume necessary to perform all of the lockages for the whole system for that year. Table 6 shows the amounts of water used at each of the nine locks in 1957.

Kentucky Use Largest--The annual total of 196,500 acre-feet released from upstream storage in 1957 to serve the lock at Kentucky Dam provided more than enough water to serve all of the nine locks. It is, therefore, considered that this quantity is the present water use for navigation through the Tennessee River locks.

TABLE 6

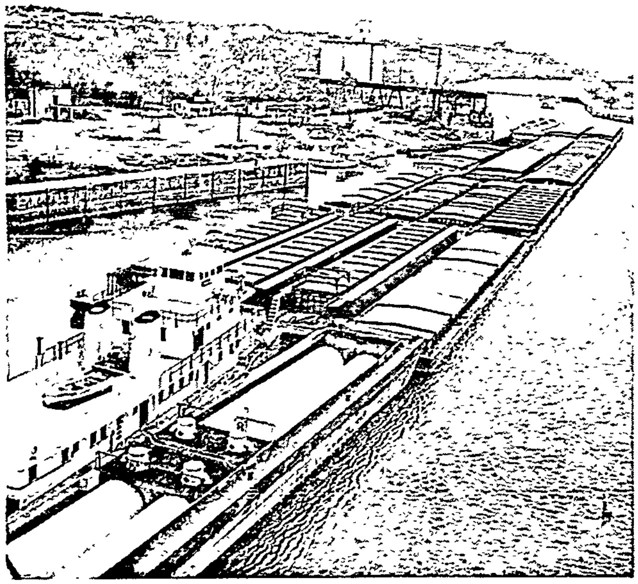
WATER USED FOR LOCKAGES IN 1957

AT TENNESSEE RIVER DAMS

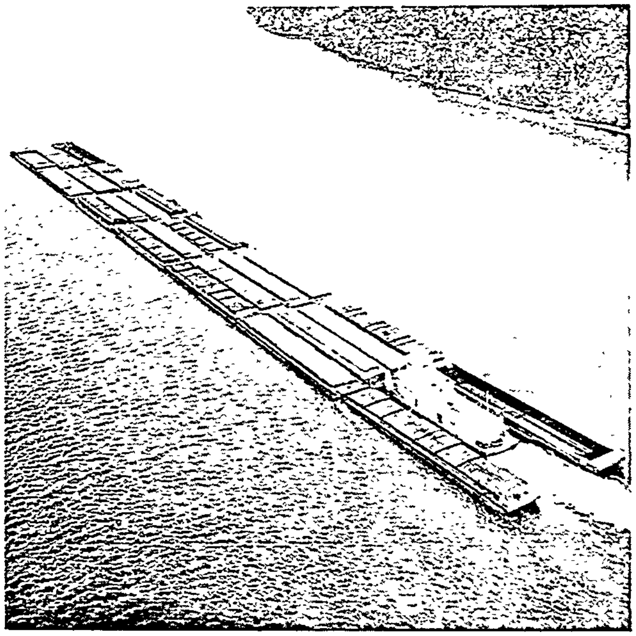
	Size of Lock - Feet			No. of	
Dam	Width	Length	Lift	Times Emptied	Volume of Water Used - Acre-Feet
Fort Loudoun	60	360	80	1,196	44,900
Watts Bar	60	360	70	1,529	46,900
Chickamauga	60	360	53	1,781	41,100
Hales Bar	60	265	41	4,134	57,700
Guntersville	60	360	45	3,904	74,900
Wheeler	60	360	52	4,020	99,000
Wilson	60	300	90	5,311	117,700
Pickwick	110	600	63	2,194	176,000
Kentucky	110	600	73	2,408	196,500

Predicted Water Use for Lockages in 1975

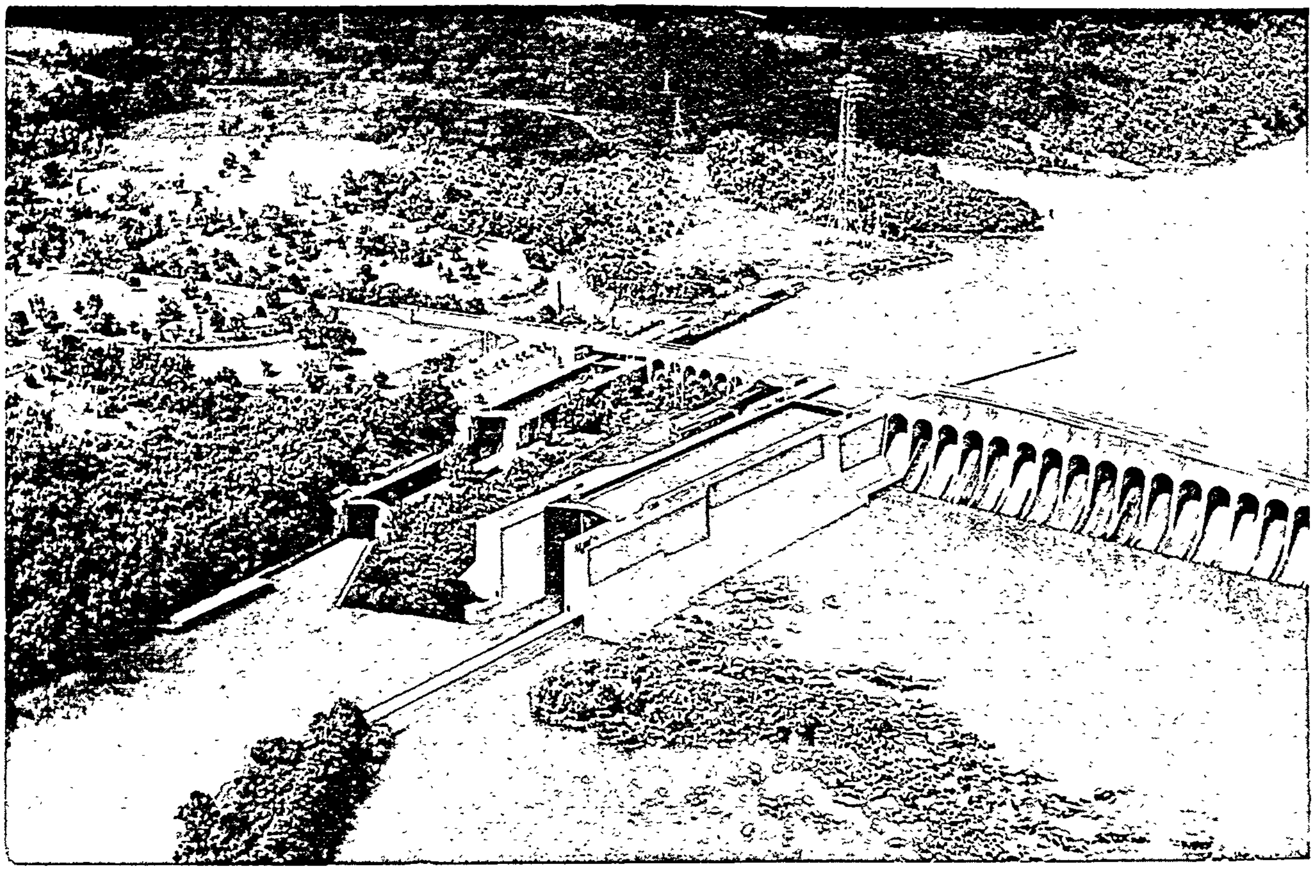
It is estimated that, by 1975, the commercial traffic on the Tennessee River will have increased more than two-fold from the present 12.6 million tons to 28 million tons. Much of this growth in traffic will come not from more intensive use of existing terminals and industries but from the establishment of new



Tow approaching old Lock No. 1 at Wilson Dam.



24-barge tow on Kentucky Reservoir.



Huge tows such as those above made a new lock at Wilson Dam essential.

plants. Preservation of the relatively few potential waterfront industrial sites available for these plants must be made a part of planning for the future if the region is to realize the maximum benefits of the waterway.

New Construction--To provide the physical facilities for handling the expected additions to the present traffic, the new lock now being built at Wilson Dam must be supplemented by 110-foot by 600-foot locks at Hales Bar, Guntersville, and Wheeler Dams. Locks of these dimensions are already in operation at the two downstream dams, Pickwick Landing and Kentucky, but additional facilities may be needed ultimately.

The canal which will ultimately be built near Grand Rivers, Kentucky, connecting Kentucky Reservoir with the reservoir above Barkley Dam on the Cumberland River will greatly improve navigation between Paducah and the Cumberland River area.

Wilson Use Largest in 1975--Table 7 shows the predicted traffic tonnage and volume of water that will be needed for lockages at each of the nine dams in 1975. It is apparent that the maximum requirements in 1975 will be the 539,000 acre-feet at Wilson Dam. If this volume of water were released from upstream storage during 1975 to provide for lockages at Wilson Dam, there would be ample water available to serve the other eight locks. It is concluded, therefore, that the total use of water for navigation lockages in 1975 would be 539,000 acre-feet.

TABLE 7

PREDICTED 1975 RIVER TRAFFIC AND WATER USED FOR LOCKAGES AT TENNESSEE RIVER DAMS

Dams	Traffic in Tons	Volume of Water Used - Acre-Feet
Fort Loudoun	2,000,000	127,000
Watts Bar	1,700,000	117,000
Chickamauga	2,400,000	81,000
Hales Bar	3,600,000	107,000
Guntersville	9,000,000	167,000
Wheeler	13,000,000	268,000
Wilson	14,100,000	539,000
Pickwick	18,600,000	387,000
Kentucky	16,300,000	470,000

Tennessee-Tombigbee Waterway--A possibility by 1975 is that a waterway connecting the Tennessee River to the Gulf of Mexico will have been placed under construction or completed. Discussion, planning, and surveying of such a waterway has been going on for at least 130 years. Latest development is the organization of the Alabama-Mississippi River Compact Authority, a bi-state agency to promote the development of such a waterway, and the appropriation of a total of $180,000 by the two states to support the agency. Early in 1959 the Tennessee Legislature passed a joint resolution making Tennessee a member of the Compact.

The presently proposed waterway would extend about 260 miles from Demopolis, Alabama, to Pickwick Landing Reservoir near Iuka, Mississippi. Minimum canal depth would be 12 feet and width 170 feet except where the canal crosses the Tennessee River divide. Here the minimum width would be 150 feet. Ten new locks 110 feet by 600 feet would be built to cover the rise from elevation 190 at Demopolis to elevation 413 in Pickwick Lake. When navigation has matured, these locks would require a diversion from Pickwick Lake of a maximum of 1,200 cubic feet per second in the dry months. The total annual diversion would be approximately 800,000 acre-feet, of which about 700,000 acre-feet would have been usable for hydro power generation.

The proposed waterway, if constructed, would provide a new transportation route of great importance to the Valley's commerce, agriculture, and industry.

HYDROELECTRIC POWER

The TVA water control program is a multiple-purpose program. Flood control and navigation are the primary activities defined by the Act of 1933; power production is secondary. The rules of operation of the multiple-purpose reservoirs give first consideration to the primary purposes. If it is necessary to spill water to maintain the flood storage reservation or the navigation channel, this is done, even though potential hydroelectric production is lost thereby.

Characteristics of Use--The use of water for hydroelectric power is a regulatory use. In quantity the Valley's hydro plants make use of nearly the whole flow of the Tennessee River. Quality limitations are negligible. The use is non-consuming and non-polluting, and the necessary storage and regulation of streamflow are generally beneficial to other users of water. The existence of the reservoirs has greatly enhanced the recreational attractiveness of the Valley, although some conflicts with recreation occur because of the summer and fall drawdown for hydrogeneration.

Number of Projects and Output--In 1958 there were 48 hydroelectric projects contributing to the TVA power system generation. TVA built 20 of these and acquired 9. The Aluminum Company of America owns 6 major projects and 9 minor ones that are integrated into the TVA system. The TVA system also distributes power generated at 4 hydro plants built by the Army Engineers on the Cumberland River. A fifth Cumberland River plant was completed late in 1958 but had not gone into full commercial operation by the end of that year. Of the total of 48 projects, 43 are inside the boundaries of the Tennessee Valley. The only hydro projects in the Valley that are not a part of the TVA system are the Carolina Power and Light Company's Walters Dam on the Pigeon River near Waterville, North Carolina, an REA plant on the French Broad River at Marshall, North Carolina, and a Cascade Power Company plant on Little River near Penrose, North Carolina.

Installed capacity at the 43 hydro projects is 3,136,600 kw. In fiscal year 1958 these and the Cumberland River projects generated a record 19.3 billion kwh or 31.7 percent of the total generation by the TVA system. The total hydro and steam generation of 60.8 billion kwh for fiscal year 1958 was more than that produced by any other power system in the United States. The estimated average year hydrogeneration for the combined system within the Valley is about 15.5 billion kwh.

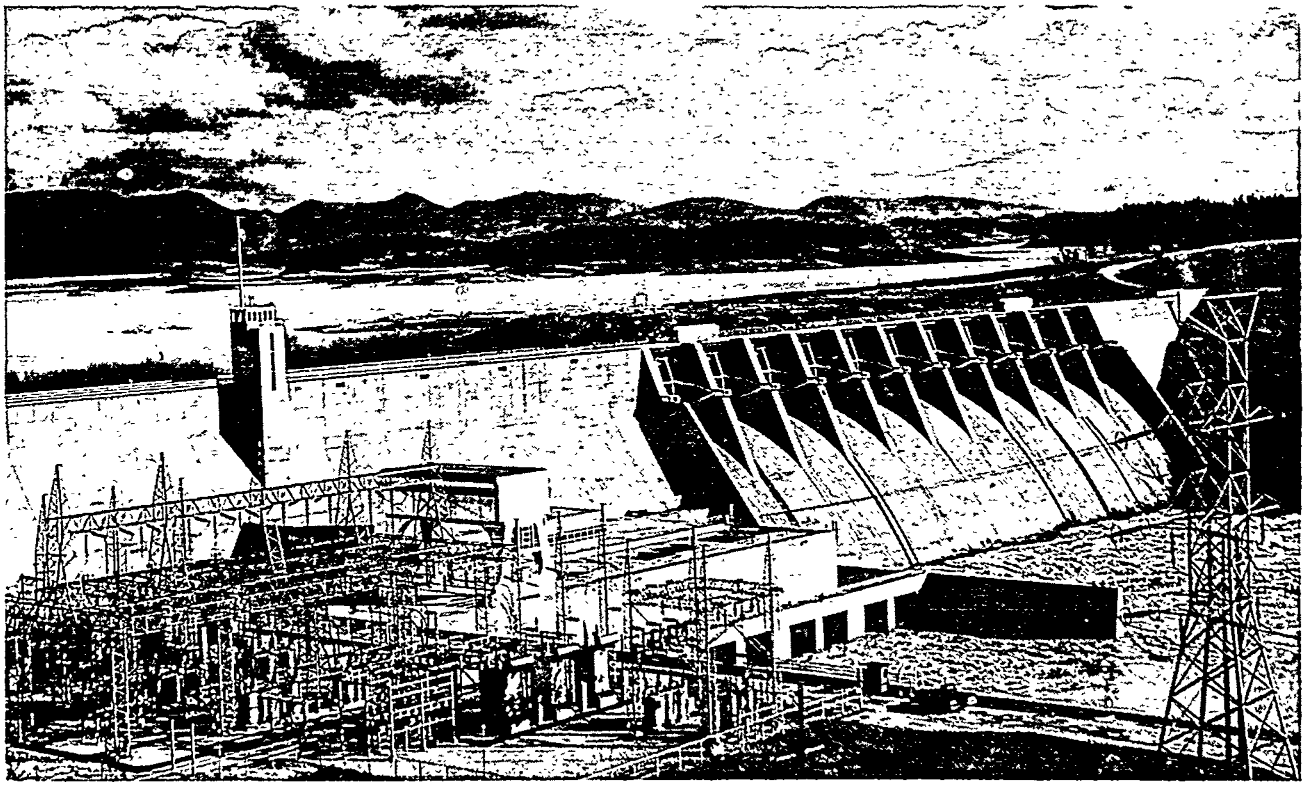
Present Water Use

Water from the headwaters of one of the Tennessee River tributaries passes over hundreds of feet of head as it moves down to the mouth of the river at Paducah. Table 8 shows some typical examples of accumulated average head at dams below the tributary reservoirs.

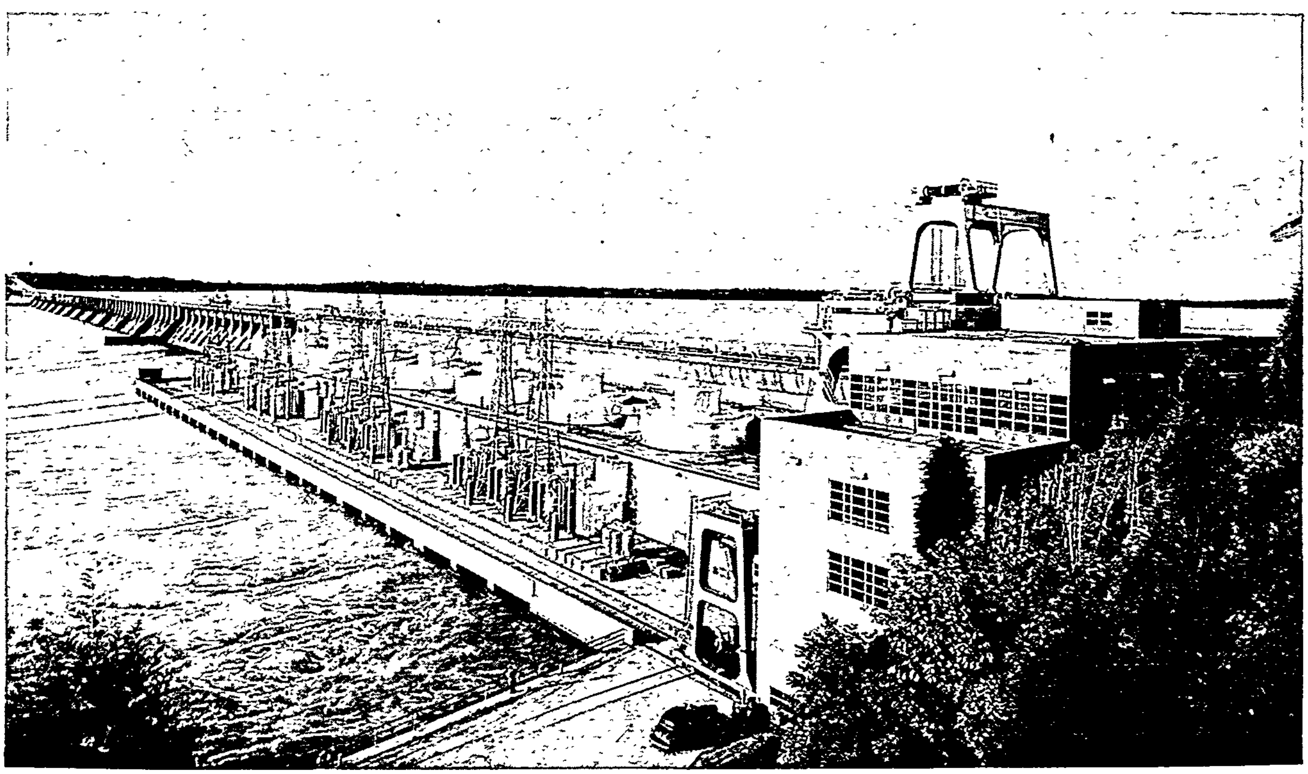
TABLE 8

TOTAL HEAD AT DAMS BELOW HEADWATER RESERVOIRS

Reservoir	Number of Dams	Accumulated Average Head at all Dams Below Reservoir Listed feet
Thorpe	13	2,415
Nantahala	13	2,195
Fontana	12	1,235
Chatuge	10	1,047
Nottely	10	1,077
Watauga	14	1,080
South Holston	13	957
Douglas	10	564
Norris	9	567



Douglas Dam and Powerhouse on French Broad River.



Wheeler Dam and Powerhouse on Tennessee River.

Typical TVA hydroelectric projects.

Because of this use of the same water over and over again for the generation of power it is impractical to add up the annual volume of water use at each of the dams and arrive at a meaningful figure. The total would be many times the actual volume of flow passing the mouth of the river.

Most of Runoff Used--Even allowing for the spilling of water during flood control operations, a large percentage of the total runoff from the Tennessee River Basin is used through the turbines of one or more dams. The amount of water that it is necessary to spill varies with the total volume of runoff from the Basin and with the distribution of that flow. Table 9 lists the percentage of annual volume of flow that was not used to generate power at representative dams during the dry year 1954 and the wet year 1957. In 1954, the spilling of water occurred principally in January at the tributary dams and in January and December on the main river. In 1957 the spilling periods were largely in February at the tributary dams and in January to March and November-December along the Tennessee River. Average flow passing Kentucky Dam in calendar year 1954 was 46,300 cubic feet per second, 70 percent of the long-term average, while in 1957 the average was 86,400 cubic feet per second, or 132 percent of the average.

TABLE 9

PERCENT OF TOTAL STREAMFLOW NOT USED THROUGH TURBINES AT SELECTED DAMS IN 1954 AND 1957

Dam	Water Spilled in Percent of Total Flow	
	Dry Year 1954	Wet Year 1957
South Holston	0	8.6
Watauga	0	0
Cherokee	0	2.3
Douglas	5.4	7.6
Fontana	0	0.4
Norris	0	19.8
Hiwassee	1.8	0
Blue Ridge	3.8	3.1
Ocoee No. 3	5.9	10.0
Fort Loudoun	1.6	10.9
Watts Bar	8.3	21.5
Chickamauga	8.9	26.4
Hales Bar	12.2	30.7
Guntersville	13.9	33.5
Wheeler	14.2	27.8
Wilson	16.4	30.5
Pickwick	16.5	32.1
Kentucky	23.5	49.8

Water Use in 1975

Slightly over 3 million kw of hydro capacity is presently installed on the Tennessee River and its tributaries. With the largest and most economically attractive hydroelectric sites already developed, only a limited number of new projects are possible by 1975.

Possible New Projects--On the Clinch River below Clinton, Tennessee, the Melton Hill project, recently approved by the TVA Board of Directors, would add an installed capacity of 72,000 kw and a navigation lock to the system. Because of the control by Norris Reservoir storage upstream, the water use at Melton Hill would be highly efficient with practically no waste of water over the spillway.

On the Hiwassee River, a possible site below the existing Apalachia project would add flood control storage and generating capacity.

In the Emory River basin above Harriman, Tennessee, a multiple-purpose project would reduce flood damages on the lower Emory River and provide a dependable flow in this stream which often goes dry or nearly dry in the late summer and fall.

An extension of Fort Loudoun Dam across the Little Tennessee River would add flood control storage and permit the utilization of the Little Tennessee River flows through the Fort Loudoun turbines.

The addition of new generating units at Wheeler and Wilson powerhouses would add system capacity and energy from water which is now being wasted. Some improvement in efficiency of use of water for power will result from the ultimate completion of the canal connecting Kentucky Reservoir with Barkley Reservoir on the Cumberland River.

Whether or not any of these projects are built by 1975 will depend on regional requirements for water, flood control, navigation, and power, as well as future economic conditions, costs and benefits.

MOSQUITO CONTROL

The control of the anopheline or malaria mosquito in large impounded waters involves a number of different measures but the most efficient and effective of these is accomplished by the cyclical manipulation of water levels. This planned water control operation is classed as a regulatory use of water. There is no consumption or deterioration of the water and, in the case of the TVA reservoirs, no significant conflict with other uses.

The day-to-day use of reservoir water as a tool for mosquito control has been made a definite and necessary part of water control operations by TVA and the Corps of Engineers. TVA adopted the plan which it now uses early in 1945, after a decade of study and experimentation.

Main River Reservoir Operation

Figure 12 shows in generalized form the plan of malaria control operation adopted for all of TVA's main-river reservoirs except Kentucky. Significant activities take place in six chronological periods. The actual dates may vary slightly from those given below.

1. January 1 to about March 15--The low reservoir levels for winter flood control help check the growth of submerged aquatics and permit marginal drainage and herbicidal operations.

2. March 15 to April 15--The early spring filling retards plant growth around the margin of the reservoir. The early April surcharge of one foot above normal full pool is a cleaning operation which strands drift and flotage above normal level.

3. April 15 to June 15--This phase, extending well into the mosquito production period, provides long-range plant growth control. Since marginal growth supplies food and protection to the larvae, this operation is a most important one.

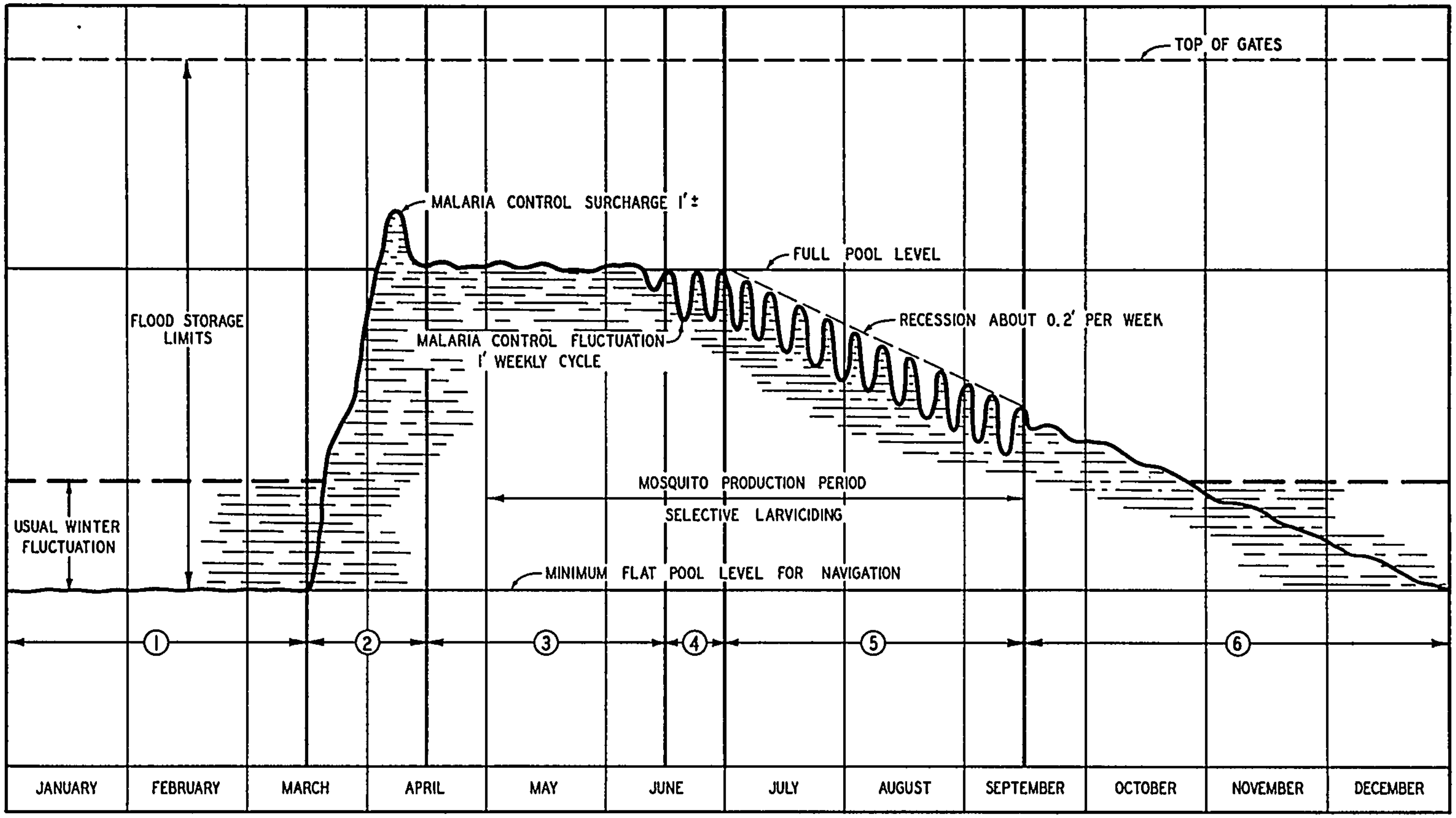
4. June 15 to July 1--This cyclical fluctuation at full pool level exposes mosquito eggs and larvae to stranding, natural enemies, and wave action.

These weekly one-foot fluctuations and those that follow them are initiated simultaneously on all of the TVA main-river reservoirs (except Kentucky). By a complex shifting of power loads, one reservoir is drawn down while the next one below is filling. No water is spilled and average head remains essentially the same through a cycle.

5. July 1 to September 15--This combination of cyclical fluctuation and recession, extending through the heaviest mosquito production period, continually draws the water level below any marginal vegetation and maintains a clean shoreline. Breeding areas are reduced; eggs and larvae are destroyed.

FIGURE 12

MALARIA CONTROL FEATURES OF WATER LEVEL MANAGEMENT ON TVA MAIN RIVER RESERVOIRS



1. LOW WINTER FLOOD CONTROL LEVELS
   Controls Growth of Submerged Aquatics— Permits Marginal Drainage and Herbicidal Operations.

2. EARLY SPRING FILLING
   Retards Plant Growth
   SURCHARGE— Strands Drift Above Full Pool Level.

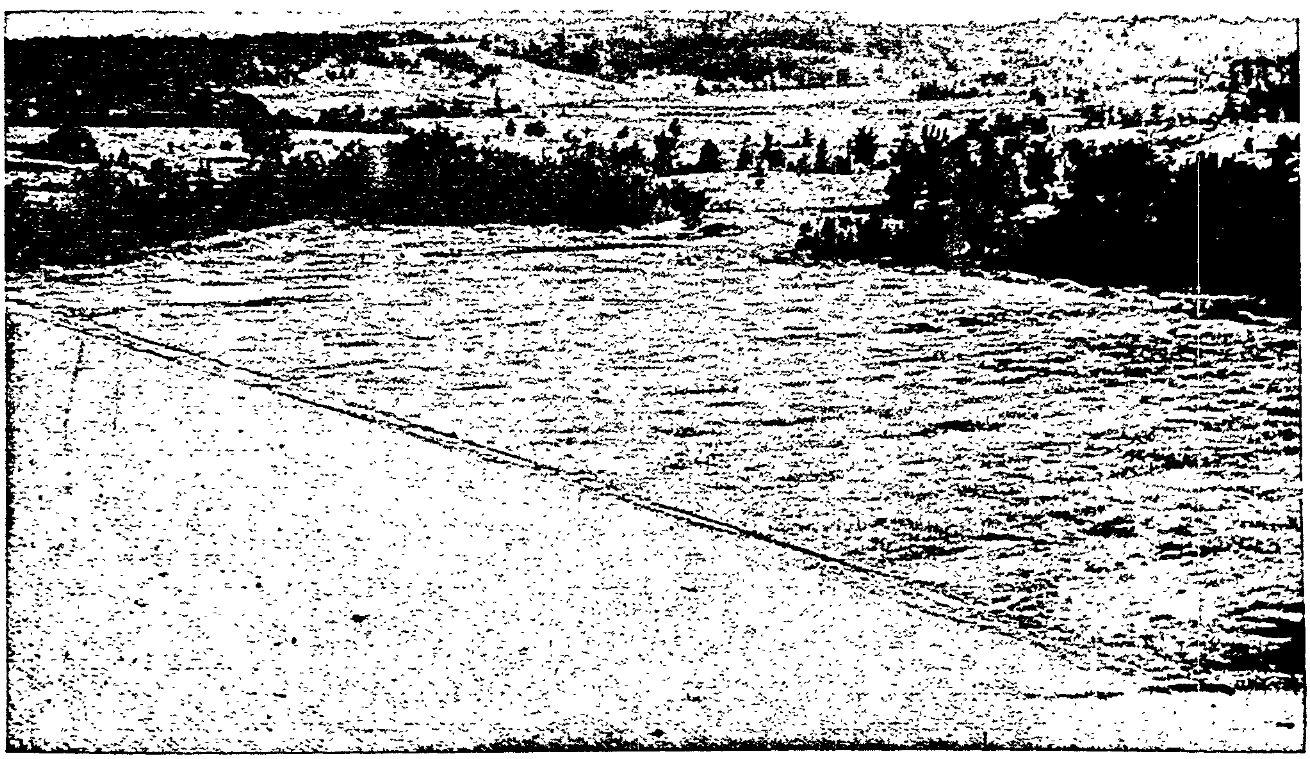
3. CONSTANT LEVEL POOL
   Provides Long-range Plant Growth Control.

4. CYCLICAL FLUCTUATION
   Destroys Mosquito Eggs and Larvae

5. FLUCTUATION AND RECESSION
   Destroys Eggs and Larvae
   Reduces Breeding Area
   Provides Clean Shoreline

6. RECESSION TO WINTER LEVELS
   Permits Fall Shoreline Maintenance and Improvement Operations.

Summertime vegetation in shallow, flat reservoir areas creates mosquito-breeding situations.



Here the mosquito-breeding potential has been built out of the shoreline area by cut and fill work.

6. September 15 to December 31--Shoreline conditioning work is carried on during this recession to winter flood control levels.

The great size of Kentucky Lake and its unique position as the final flood control point on the river, make it impractical to carry out cyclical water level fluctuations on this reservoir. A three-phase management schedule is used, consisting of a spring surcharge, a relatively constant pool level during the spring growth period, and a summer and fall recession of 3 to 5 feet.

Tributary Reservoir Operation

The anopheline mosquito production period begins later and ends earlier in the climatic situation of most of the storage reservoirs than it does along the main river. The wide seasonal recession common to all of these reservoirs occurs during the heavy mosquito production period and provides ample mosquito control without cyclical fluctuations. The typical steep shorelines have relatively low soil fertility, and marginal vegetation is not a problem.

Control on Small Reservoirs

There are now over 50,000 farm ponds and small reservoirs in the Tennessee Valley. Many of these create a potential malaria hazard. Most Valley State Health Departments have regulations that require clearing, ditching of depression areas, flotage removal, and installation of some means of water-level control on these farm ponds and other small reservoirs.

Value of Program

The TVA's experience proves the effectiveness of water-level management for the control of the anopheline mosquito. Since 1948 there has not been a single case of malaria in the Valley that could be traced to mosquitoes originating in TVA lakes.

Present Use of Water

Enormous volumes of water are manipulated in the cyclical fluctuations of TVA's mainriver reservoirs for malaria control. Counting each one-foot rise or fall as a separate operation, there are over 300 fluctuations each year in the nine reservoirs combined, involving the addition or removal of 11,000,000 acre-feet of water in the 12 months. While this operation is not always fully compatible with use of water for power generation, no significant waste of water is involved. The use is generally non-consuming, non-polluting, and to a large extent non-conflicting.

Water Use in 1975

Water level management will continue to be the backbone of the malaria mosquito control program in the foreseeable future, supplemented as needed by chemical control measures.

The needs of the malaria control program will tend to increase with increased use of the lakes for recreation and greater development of lakeshore property. Offsetting these factors are (1) the cumulative effect of past water level management, (2) the anticipated development of more potent and longer lasting larvicides and herbicides, and (3) the development of more effective methods of application of these chemicals.

Upon weighing these factors, it appears that the program in 1975 may be shifted in location, scope, and timing but that, in terms of water use, there will be no significant change from the present.

WITHDRAWAL USES

IRRIGATION[1]

The extraordinary growth of supplemental sprinkler-type irrigation in the humid East during the past few years has aroused more interest in water policy and water programs than any other single occurrence. In the Tennessee Valley region, where the development of this use has largely paralleled that of other Eastern areas, the concern with irrigation's ultimate effect on other uses has been the prime cause for examinations of existing water resource legislation by several Valley states.

Characteristics of Use--Irrigation is the most consumptive of the withdrawal uses and for this reason it presents an important and increasing potential conflict with all other uses. All unpolluted waters of the Valley and many of the less polluted streams are suitable for irrigation use. The use itself causes no pollution.

Growth of Irrigation in the Valley

Irrigation systems of the sprinkler type date back at least to 1910 in the Tennessee Valley. By 1950 there were still less than 100 systems operating within the Valley boundaries. Rapid growth in the use of supplemental irrigation began in 1951, the first of a series of six consecutive dry crop seasons. Some 880 irrigation systems were installed between 1950 and 1957. Thirty per-cent of these were established in 1954, the third driest crop season of record in the Valley. By 1957 there were approximately 950 systems in operation, irrigating 37,000 acres.

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1. A more detailed presentation of supplemental irrigation in the Valley agriculture may be found in "Agricultural Use of Water in the Tennessee Valley," Division of Agricultural Relations, TVA,1958.

Size and Distribution of Irrigated Acreage

Approximately 40 percent of the irrigation systems are used to irrigate areas of 10 acres or less. Another 39 percent of the systems are used on areas of 11 to 50 acres. At the other extreme, three systems irrigate 400 to 475 acres.

Principal Concentrations--The French Broad River basin contains the heaviest concentration of irrigation systems, some 37 percent of the Valley total. About 180 of the 340 systems in the French Broad River basin are in the North Carolina portion and the remaining 160 are in the Tennessee part of the basin. Most of these systems are used on tobacco and vegetable crops, and the irrigated areas average about 25 acres per farm. Another sizable group of irrigation units is located in northern Alabama, particularly in Limestone and Madison Counties. Used mainly on cotton, the 65 systems in these two counties cover an average of 100 acres each. Other groupings in the Valley follow the general trend of the Holston and Tennessee Rivers from Virginia to northwest Georgia and the Central Basin portions of the Elk and Duck Rivers.

All but about a dozen systems in the Valley are of the sprinkler type. The exceptions use furrow irrigation on small acreages where gravity feed from water source to crop is feasible.

Crops Irrigated

Pasture is the most extensively irrigated crop in the Valley. Thirty-two percent of all irrigated acreage is in pasture. Next is corn with 18 percent, hay and feed 16 percent, truck crops and gardens 15 percent, and cotton 12 percent.

Many of the irrigation systems in the Valley were originally installed for use on such high-value crops as tobacco and vegetables, but these systems are also being used on lower value crops when time and water are available. Tobacco, for example, is irrigated on only 2.5 percent of the acreage, yet 45 percent of the farmers with systems irrigate tobacco and some other crop. This practice tends to decrease the per acre costs of operating the irrigation system, thus decreasing the burden borne by a few high-value crop acres in carrying the relatively high fixed charges of the investment. In general, the higher value crops have yielded the greatest returns from irrigation, even when grown in the higher rainfall portions of the Valley. However, under good management and in areas experiencing frequent droughts, irrigation is known to be profitable on such extensive crops as hay and pasture, especially when utilized by Grade A dairies. This can be done profitably only when the added costs are more than covered by the added returns from irrigating the additional acreage.

Investment in Systems

The total 1957 investment in irrigation systems in the Valley is $3,500,000. Average investment per irrigated acre is $95. Individual costs range from $100 for a system used on a fraction-of-an-acre tobacco patch in North Carolina to $75,000 for a semi-permanent system covering 350 acres of cotton in northern Alabama. The average cost per system ranges from $1,900 in North Carolina to $7,800 in Alabama and is $3,700 for the Valley as a whole.

Sources of Water

Surface water is the principal source of supply for irrigation in the Valley. About 84 percent of the systems use water from streams or from TVA reservoirs to irrigate 89 percent of the acreage. Another seven percent use springs and five percent use ponds. Only four percent of all the systems pump water from wells. The only important use of ground water is in northern Alabama where 14 farmers use wells to irrigate 1,300 acres.

Consumptive Use

Most authorities agree that a high percentage of the water applied to crops by means of sprinkler irrigation is transpired by the crops or is evaporated from the land and leaf surfaces. Some estimate this consumption at 100 percent. If the amount applied is no more than enough to replace the soil moisture in the root zone and to satisfy surface evaporation, this is true. Others say that since irrigation is best carried out on soils with good internal drainage, some of the applied water is bound to seep down beyond the root zone to the ground-water table. There will be times also in the humid East when rains will follow shortly after irrigation so that the irrigation will in effect increase ground water or surface runoff from the rain. A study recently completed by the Agricultural Research Service showed that, over a 7-year period, irrigation preceding rainfall increased runoff 27 percent from continuous sweet corn and 10 percent from sweet corn following sod. For the purpose of this study the consumptive use has been arbitrarily set at 90 percent.

Water Used in 1956

A determination was made of the water used to irrigate 35,840 acres of crops in the Valley in 1956, based on information obtained during an inventory of irrigation systems. The 1956 crop season rainfall was rather erratic over the area but in general the season was slightly more "droughty" than the median. Drought conditions were confined almost entirely to the four months June-September, and most of the irrigation was carried out in these months. Practically all of the farmers who were interviewed depended on experience and judgment in determining when and how much to irrigate. The results of the 1956 determination for each of ten major drainage basins of the Valley are presented in table 10.

TABLE 10

ESTIMATED WATER USE FOR IRRIGATION

IN JUNE-SEPTEMBER 1956

Drainage Basin[a]	Acres Irrigated	Water Applied Inches Per Acre	Water Applied Volume Acre-Feet	Estimated Streamflow Acre-Feet (b)	Use in Percent of Flow
Tennessee River - Mouth to Pickwick Dam	1,050	5.2	500	281,000	0.2
Duck River	1,640	7.2	1,000	265,000	0.4
Tennessee River - Pickwick to Guntersville Dam	6,910	8.8	5,100	476,000	1.1
Elk River	4,650	7.5	2,900	210,000	1.4
Tennessee River - Guntersville to Knoxville	5,330	6.1	2,700	485,000	0.6
Sequatchie-Emory Rivers	260	5.5	100	122,000	0.1
Hiwassee-Little Tennessee Rivers	2,460	5.7	1,200	1,270,000	0.1
Clinch River	1,770	5.0	700	502,000	0.1
Holston River	3,550	6.0	1,800	507,000	0.4
French Broad River	8,220	5.1	3,500	934,000	0.4
Tennessee Valley	35,840	6.5	19,500	5,052,000	0.4

(a) See figure 6 for location.

(b) Based on runoff from the local basin area only and not including flow in the Tennessee River from basins upstream.

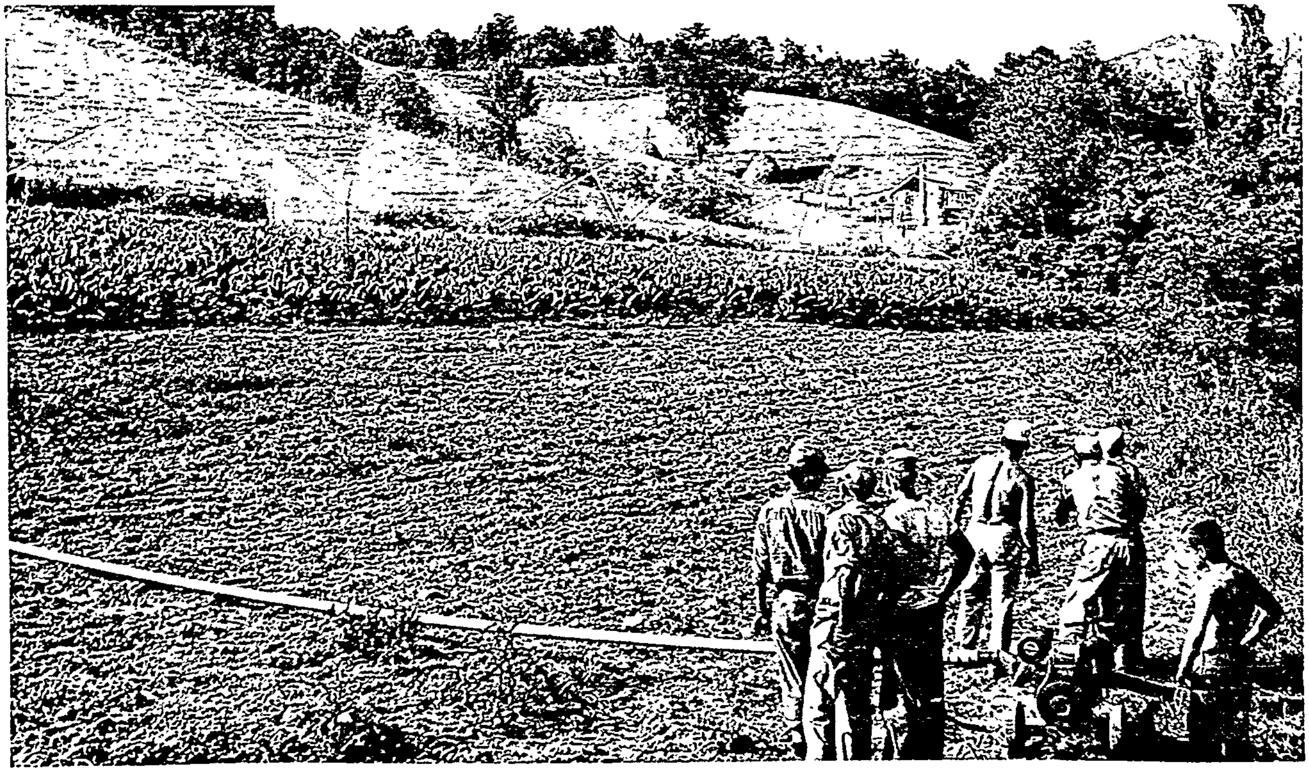
Local Shortages--The irrigation use was a very small part of the total June-September streamflow on a basin-wide basis. Local shortages did occur in 1956. On Limestone Creek in Alabama, the heavy demands of a dozen cotton irrigators nearly dried up the stream. On several small streams in the French Broad River area, farmers voluntarily agreed to alternate their pumping periods so as not to dry up the streams.

Economic Aspects of Irrigation

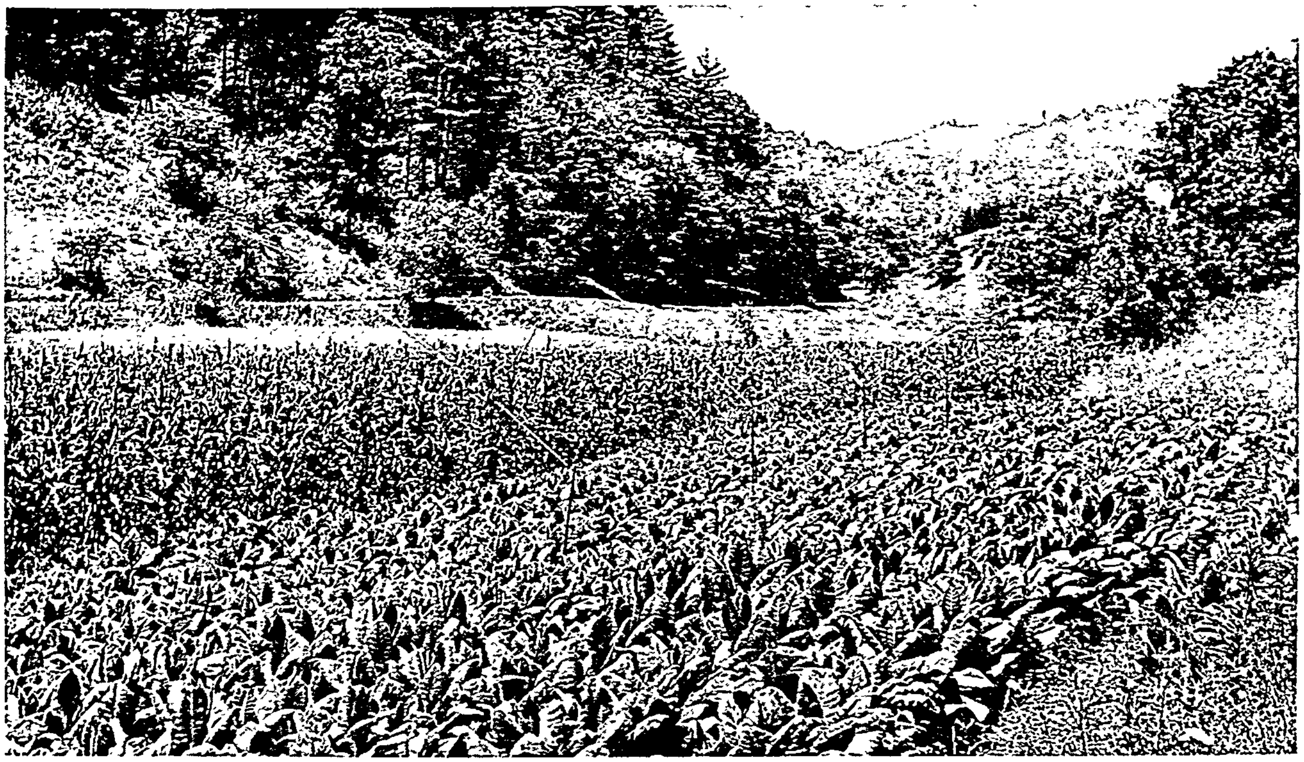
The large investment required to include irrigation in the farming operation requires a major decision by the farmer, since the long-run economic benefits of irrigation in the Valley are still largely unknown. Because of the close relation between time and intensity of drought and the need for irrigation, the returns from this practice will vary from year to year. The problem is to consider the returns from irrigation use over sufficiently long periods of time to cover a sufficient range of soil moisture conditions. Another important consideration is that the returns from irrigation may vary in different sections of the Valley due to differences in soils, the time when drought occurs, and the kind of crop grown.

Alternative Investments--Benefits to be derived from irrigation must be sufficient not only to cover costs, but they must be greater than those that may be obtained from other possible alternative investments. Generally, farmers with relatively limited capital may secure a greater return from such alternative investments as fertilizer, improved seed, machinery, or more productive livestock than from irrigation. Farmers possessing good management and adequate capital may expect relatively less profit from these alternative forms of investment, and a greater return from an irrigation system if the farm is favorably situated with respect to soils and water.

Irrigation Stabilizes Yields--An important factor in determining the benefits from irrigation is the stabilization of yields. Some farmers may willingly accept a smaller amount of total net earnings over a period of years if they can be more assured of a fairly constant income. This consideration may account for many systems being installed in the less droughty portions of the Valley to



These neighbors in Madison County, North Carolina, share this small irrigation system, moving it from farm to farm.



Irrigation systems are used principally on tobacco in Western North Carolina.

irrigate truck, nursery, and tobacco crops where a single drought year could cause a great loss in income.

The value of irrigation in stabilizing yields is also important on pasture and livestock farms. Farmers frequently plan to use less of their pasturage than is available in average crop years, and thus fail to utilize all the feed available in better than average crop years. The use of an irrigation system enables a farmer to stock pastures at a level which more adequately utilizes the forage that the land will produce. Pasture irrigation for dairy cows has attracted considerable interest in this region because of the above consideration and because milk flow can be maintained during drought periods, when substantial losses in income often occur. Irrigation alone will not guarantee a high pasture yield or a high rate of return. In order to be highly profitable, this practice must be used in combination with other improved production practices, such as selection of the proper pasture species, adequate fertilization, and timeliness in all operations.

Depreciation of Systems--An irrigation system is usually expected to be fully depreciated in about 15 years, and the total return from the investment is also spread over this period. Since an income expected to be gained at some future date is often worth less to a farmer than the same income received now, he may discount future benefits somewhat in arriving at the present value of his system. Although the rate of discounting is largely subjective and varies with different individuals, 10 to 15 percent appears to be realistic under present circumstances and over a time period sufficiently long to fully depreciate an irrigation system.

Outlook for the Future

Future needs for water for irrigation in the Tennessee Valley are difficult to estimate. There is a lack of sufficient experimental data that can be interpreted in economic terms. The profitability of irrigation at the present time is limited largely to high-value crops such as vegetables, tobacco, nursery crops and, in some cases, dairy pastures. Further irrigation will prove successful only when farmers have built up the fertility of their soils and adopted other improved cultural practices. Supplemental irrigation is not a substitute for other good management practices, and it is only when these are used at a high level under conditions where water is the chief limiting factor that irrigation can grow on a sound basis. Thus an estimate of the future expansion of irrigation will necessarily be governed by complex economic and management factors.

Valley Land Suitable for Irrigation--There is no shortage of land physically suitable for irrigation in the Valley. A study made by TVA agriculturists and soil specialists showed approximately 1.7 million acres of land within reasonable distance of adequate supplies of surface water that were at least suitable for this practice.

In this study the lands considered for suitability were those within a band lying along existing sources of surface water. It was assumed that the individual farmer could not afford to irrigate fields more than one-half mile away or 100 feet above the water source. Exceptions were made in certain broad areas having a high proportion of irrigable soils, and the band was extended to 5 miles away from and 150 feet above the water source. Irrigation at such distances would probably be economical only through cooperative efforts by farmers.

Soils in these bands were divided into four suitability groups, based on physical characteristics and associations. These groups were classed as very well suited, well suited, suitable, and very poorly suited or not suited. Each group was further subdivided into primary areas or those in the one-half mile band, the special one-half to five-mile areas, and tributary areas. The latter are in a one-half mile band along small streams with flow generally much less than that needed to irrigate the potential acreage. Results of the study are shown in table 11.

Future expansion of irrigation will not necessarily take place in the very well suited soils before moving into the next two groups. Farmers would probably irrigate in all three groups, depending on arrangement of fields, soil patterns, severity of drought, and other influencing factors.

TABLE 11

LAND WITHIN IRRIGABLE DISTANCE OF SURFACE WATERS

Suitability Group	Area in Acres			
	Primary	Special	Tributary	Total
Very well suited	375,500	113,900	168,100	657,500
Well suited	277,300	283,900	60,700	621,900
Suitable	213,600	114,800	73,700	402,100
Total suitable	866,400	512,600	302,500	1,681,500
Not suited	700,800	91,300	161,500	953,600
Grand total	1,567,200	603,900	464,000	2,635,100

Factors Influencing Expansion--Some of the more direct benefits from irrigation that could influence the profitability of the practice include (1) increasing the stand and yield of crops; (2) insuring a relatively uniform yield from year to year; (3) reducing losses from frosts; (4) lengthening the grazing season, and (5) increasing opportunities for double cropping. Each of these benefits would be most important in the high-value crops, or those under acreage allotment. Best realization of these benefits requires that irrigation be used with improved cultural practices, improved seed and seed treatment, and the use of improved fertilizer practices, including the proper rates of fertilization. The use of irrigation makes possible an increase in the economical levels of fertilization.

Some possible deterrents to expansion are (1) lack of assured water supply; (2) lack of know-how, and reluctance to adopt new practices that require entirely new skills and techniques; (3) high capital outlay and difficulty of financing; (4) high and unpredictable labor requirements; (5) marketing uncertainties for high-value crops, and (6) new problems of plant disease, insects, and weeds.

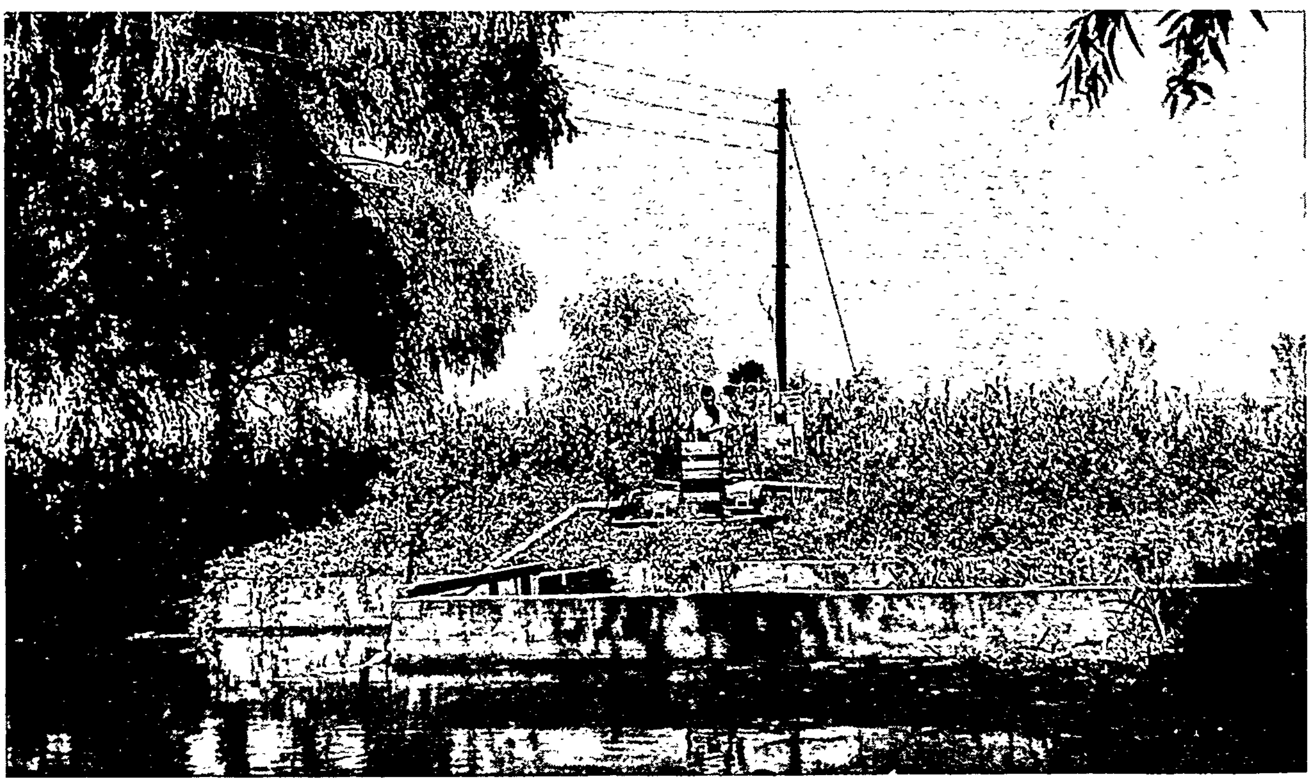
Basis of Predictions--In making predictions as to the growth of irrigation in the Valley by 1975, it has been assumed that (1) the current trend in population growth and subsequent increased demand for agricultural products will continue; (2) present world conditions will prevail; (3) the improvement in levels of consumption and living standard will continue; (4) industrialization of the Valley will continue at a rapid rate; (5) livestock and livestock products will provide an increasingly larger share of agricultural income; (6) population shifts from farm to non-farm will continue; (7) the trend toward a decreasing acreage of cropland will continue, though at a slower rate; and (8) increased demand for agricultural products will be met largely by increasing productivity.

As an added basis in making realistic projections of the future expansion of irrigation, an attempt was made to correlate the important factors affecting expansion to that which had occurred in past years. The relatively recent history of irrigation growth in this region and the lack of prior knowledge of how the various factors influence this expansion place limitations on this procedure, but the information obtained from this analysis proved useful as a "first approximation" of the expected increase. Estimates of the 1975 acreage in each of the ten major areas of the Valley were based on this analysis together with the best judgment of a number of specialists in the Valley agriculture, taking into account as many of the influencing factors as possible.

Predicted Acreage Irrigated in 1975—Table 12 summarizes the predictions of 1975 irrigated acreages for each of the 10 drainage basins and compares them with the acreage actually irrigated in 1956. The predictions are given as a range of values. The spread is roughly 12 percent.

In subsequent determinations of 1975 water use for irrigation only the high values of the prediction will be considered.

Irrigating turnips in Catoosa County, Georgia.



This farmer pumps irrigation water from a large spring-fed lake.

TABLE 12

PREDICTED IRRIGATED ACREAGE IN 1975

Drainage Basin[a]	1956 Irrigated Acreage	1975 Predicted Acreage Low Estimate	High Estimate	Percent of 1956 Acreage (b)
Tennessee River - Mouth to Pickwick Dam	1,050	2,000	2,500	238
Duck River	1,640	8,000	9,000	549
Tennessee River - Pickwick to Guntersville Dam	6,910	27,000	30,000	434
Elk River	4,650	7,500	8,500	183
Tennessee River - Guntersville to Knoxville	5,330	10,000	12,000	225
Sequatchie - Emory Rivers	260	1,000	1,500	577
Hiwassee-Little Tennessee Rivers	2,460	4,000	5,000	203
Clinch River	1,770	4,000	5,500	311
Holston River	3,550	7,000	9,000	254
French Broad River	8,220	16,000	20,000	243
Tennessee Valley	35,840	86,500	103,000	287

(a) See figure 6 for location.

(b) Using high prediction only.

Irrigation Water Requirements in 1975

The predicted 1975 irrigation would not cause a serious drain on the water resources of the Valley as a whole or on the total summertime flow of any of the 10 major drainage basins. Serious small area shortages will undoubtedly occur, and the data indicate that these may be largely on the tributary streams in the northern Alabama area and in the Duck and Elk River basins.

Basis of Computations--Computations have been made of the probable use of water to irrigate the predicted 1975 acreages on the basis of a recurrence of the rainfall and streamflow of the dry 1954 crop season and the average 1956 season. The following assumptions were made: (1) the distribution of irrigated crops on the 1975 predicted acreage will be in the same proportion as was actually grown in 1956; (2) the amount of water needed by crops in a recurrence of the dry 1954 season will be determined from drought-day computations for 1954 conditions; (3) the efficiency of application of water in a 1954 season will be 75 percent; and (4) a recurrence of the 1956 season will require the same application of water per acre as was actually used in 1956.

The 1954 drought-day data showed no need for irrigation in April or May. Irrigation in a season with weather conditions similar to those of 1954 would continue from June into October whereas the 1956 season included only the four months June-September.

Estimated Water Use--Tables 13 and 14 show the results of the projected 1975 water use estimates, based on conditions similar to 1954 and 1956. In a dry 1975 season, table 13, a maximum of about 80,000 acre-feet of water would be used on the predicted acreage. Applications in the first six basins listed would range from 9 to 12 inches per acre and in the next four from 6 to 8 inches per acre. The average for the Valley in a dry year would be 9.4 inches per acre, about 40 percent more than that applied in 1956.

TABLE 13

ESTIMATED WATER USE FOR IRRIGATION IN 1975

DRY YEAR - 1954 RAINFALL AND STREAMFLOW

Drainage Basin [a]	June-October Total Acre-Feet: Water Required For Irrigation	June-October Total Acre-Feet: Estimated Streamflow (b)	Use in Percent of Streamflow
Tennessee River - Mouth to Pickwick Dam	2,400	308,000	0.8
Duck River	8,400	299,000	2.8
Tennessee River - Pickwick to Guntersville	30,300	404,000	7.5
Elk River	7,900	153,000	5.2
Tennessee River - Guntersville to Knoxville	10,400	427,000	2.4
Sequatchie-Emory Rivers	1,100	87,000	1.3
Hiwassee-Little Tennessee Rivers	3,300	1,293,000	0.3
Clinch River	2,700	328,000	0.8
Holston River	4,600	315,000	1.5
French Broad River	9,300	715,000	1.3
Tennessee Valley	80,400	4,329,000	1.9

(a) See figure 6 for location.

(b) Based on runoff from the local basin area only and not including flow in the Tennessee River from basins upstream.

TABLE 14

ESTIMATED WATER USE FOR IRRIGATION IN 1975

AVERAGE YEAR - 1956 ACTUAL WATER APPLICATION

Drainage Basin[a]	June-September Total Acre-Feet: Water Required For Irrigation	June-September Total Acre-Feet: Estimated Streamflow (b)	Use in Percent of Streamflow
Tennessee River - Mouth to Pickwick Dam	1,100	281,000	0.4
Duck River	5,400	265,000	2.0
Tennessee River - Pickwick to Guntersville	22,000	476,000	4.6
Elk River	5,300	210,000	2.5
Tennessee River - Guntersville to Knoxville	6,100	485,000	1.3
Sequatchie-Emory Rivers	700	122,000	0.6
Hiwassee-Little Tennessee Rivers	2,400	1,270,000	0.2
Clinch River	2,300	502,000	0.5
Holston River	4,500	507,000	0.9
French Broad River	8,500	934,000	0.9
Tennessee Valley	58,300	5,052,000	1.2

(a) See figure 6 for location.

(b) Based on runoff from the local basin area only and not including flow in the Tennessee River from basins upstream.

Heaviest monthly use of water for irrigation over the Valley in a dry year would be 33,000 acre-feet in July. Nearly 90 percent of the total dry year irrigation water over the Valley would be applied in the three months July-September.

Use in Critical Areas--Some 38 percent of the Valley total water use for irrigation in a dry season would be used in the northern Alabama area where both the acreage and the application per acre are at a maximum. Irrigation in this area in a dry year would require 14 percent of the area's small stream runoff in July, 26 percent in August, 6 percent in September, and an average of 7.5 percent for the season. These heavy drains on the small stream runoff would force greater use of the ample supplies in the Tennessee River wherever these could be economically reached.

In the Elk River area, the dry year use of water for irrigation in 1975 would take 10 percent of the total basin flow in July, 17 percent in August, 11 percent in September, and 5.2 percent for the season. The proportionate demand for this use on some of the smaller streams would be much heavier than these percentages.

RURAL DOMESTIC

The water that is needed for domestic purposes on nearly 200,000 farms and in many rural homes in the Tennessee Valley is classed as a withdrawal use. Included is water used for homes, sanitation and cleanliness around the farmstead, irrigating lawns and small gardens, and watering livestock. Dairying requires substantial quantities of water for cleaning barns and cooling milk.

Characteristics of Use--Water for home use in the rural areas comes almost entirely from cisterns, wells and springs, with wells being the predominant source. Quality requirements must be high since little or no treatment is used. Water for livestock is supplied from wells, cisterns, springs, surface streams, and to an ever growing extent from farm ponds. By far the greatest use made of the numerous farm ponds in the Valley is for watering livestock.

Consumptive Use--The degree to which water is consumptively used in rural homes is not well known. There is probably a fairly high percentage of return in the households with running water, since most of these homes will have some type of sewage disposal system. There is undoubtedly some small return to ground water and surface water from the water used in non-piped homes and by livestock. Since nearly half of the present rural use in the Valley is in piped homes with an estimated 90 percent recovery and about half in unpiped homes and by livestock with about 10 percent recovery, an approximate consumptive use estimate of 50 percent has been assumed. By 1975, with more use of piped water, consumptive use will probably decrease to about 40 percent.

Present Water Use

No inventory has been made of water use on farms and rural homes in the Valley. The Census of Agriculture for 1954 includes information from which numbers of farm and rural households and livestock can be determined. Water use can be estimated by multiplying these values by generally accepted water-use factors for household and livestock uses.

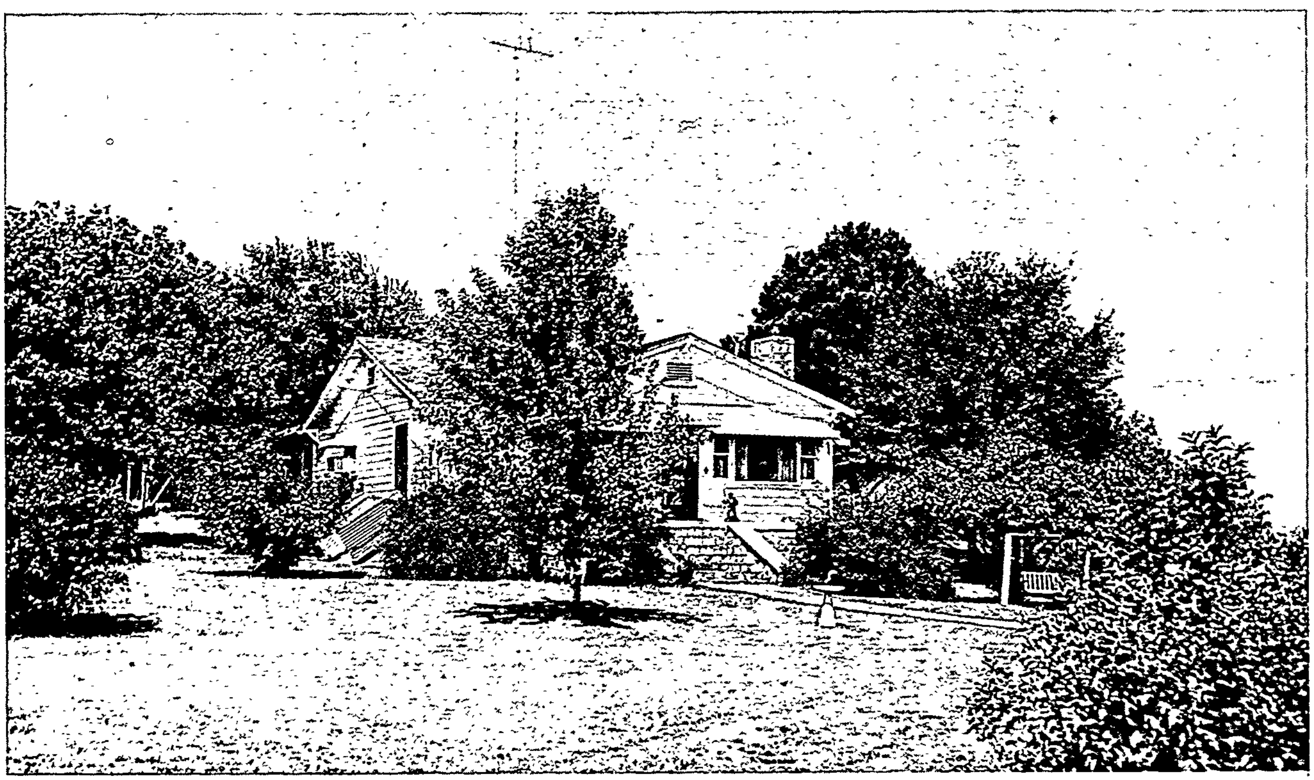
The factors used in this calculation were the following:

	Per Capita Use Per Day in Gallons
Homes with piped water	60
Homes without piped water	10
Milk cows	30
Other cattle	12
Horses and mules	12
Sheep	2
Hogs	3
Chickens	0.04

Approximately 45 percent of the farms in the Valley had piped water in 1954. In counties west of Chattanooga, percentages of farms with piped water ranged from 16 to 55 while east of Chattanooga the range was from 26 to 71 percent. The highest percentages of piped farms were in the North Carolina counties. A large proportion of the rural farm population in these counties are part-time industrial workers with relatively high family incomes.

From these data the rural domestic water use in the Valley has been estimated as shown in table 15. The total volume of domestic use shown in the table is at the average rate of 68 million gallons per day.

The 1954 Census of Agriculture showed that about half of the farm homes in the Valley did not have piped water.



This farm home in northern Georgia has all the modern conveniences including a water distribution system.

TABLE 15

PRESENT ANNUAL RURAL DOMESTIC WATER USE

IN THE TENNESSEE VALLEY

(Based on 1954 Census Data)

Use	Quantity Used in Acre-Feet
Households	36,000
Cattle	30,900
Other stock and poultry	8,800
Total	75,700

Water Use in 1975

The trend in recent years has been for the size of farms to increase and for farm population to decrease. There has been a partly offsetting trend for urban residents to move into rural areas on a part-time farming or non-farming basis. Between 1956 and 1975 a net decrease in rural population of about 200,000 is expected from the 1956 level of just under one million people.

With larger farms requiring better water distribution and with more transplanted urban families accustomed to the convenience of running water, it is expected that the number of piped rural homes will increase to about 80 percent of the total by 1975 and that per capita use will approach that of urban residents or about 100 gallons per day. Numbers of cattle, hogs, sheep, and chickens are expected to increase from 10 to 20 percent by 1975. Work stock will decrease about 15 percent.

With these data and with other factors remaining the same as at present, the 1975 rural domestic water use has been estimated at 121,100 acre-feet as shown in table 16, or at an average rate of 108 million gallons per day.

TABLE 16

1975 ANNUAL RURAL DOMESTIC WATER USE

IN THE TENNESSEE VALLEY

	Quantity Use In Acre-Feet
Households	73,800
Cattle	37,600
Other stock and poultry	9,700
Total	121,100

MUNICIPAL WATER SUPPLIES

Furnishing water to urban residents of the Valley is one of the most essential of the water uses. Nearly two million of the Valley's three million people are dependent upon urban water supplies. Most small industries and many larger ones obtain water from municipal systems.

Characteristics of Use--Supplying water to municipalities is a withdrawal use. Quality requirements are high; seasonal variations are moderate but increasing; and consumptive use averages about 10 percent of the total. The degree of pollution varies with the treatment given the water before it is returned to the Valley streams. Conflicts exist, principally because of the pollution factor.

Number of Systems--There are 343 water systems presently operating in the Valley. Of these, 195 are municipally owned, 42 are organized as utility districts, and 106 are owned by private companies, individuals, industries, or units of state or Federal government. Seventeen of the 20 largest systems in the Valley are municipally owned.

Sources of Water

The source of water supplies for cities in the Valley varies with the size of the city. In general, the small communities use ground water, either from springs or wells. The medium sized cities supplement ground-water sources with surface water. The large cities depend entirely on surface water.

A total of 181 public water supplies are taken entirely from springs or wells; another 35 supplement these supplies with surface water, while 127 systems use surface water exclusively. Approximately 1,232,000 people or two-thirds of the urban population of the Valley are furnished with water from surface supplies. If the surface water designation is considered to include all sources except water from wells, then the streams, springs, and lakes of the region furnish about 90 percent of the total volume of water involved in this use.

The Utility District Trend

The expansion of public water systems to serve suburban areas has been one of the most prominent characteristics of recent years in the field of water supply. The movement of city dwellers to the suburbs has caused an increasing demand for water main extensions. When further extension of the municipal system becomes impractical, the independent utility district, water authority, or sanitary district takes over.

The larger cities in the Valley have seen much of this type of development in the unincorporated areas. Chattanooga, Knoxville, and Asheville are surrounded by utility districts. The Kingsport-Johnson City-Bristol area is interlaced with 18 utility districts. No abatement of this trend is presently in sight.

Quality Requirements

Water supplied for domestic purposes should be clear and free of taste, color, and odor. It should be relatively low in dissolved minerals and should not be unreasonably hard. It should contain no toxic materials, and it must be bacteriologically safe.

Many wells and springs produce water that meets these requirements without treatment. Most surface waters are treated to some extent. Modern water-treatment technology has advanced to the point where practically any fresh water source can be treated to produce an acceptable finished water for domestic use.

Quantity Requirements Per Capita

Per capita water use in a city is determined by dividing census population into the average daily municipal water use in gallons. Included in the total is domestic use within the city and in the connected fringe area outside; use by service operations, and use by industries connected to the municipal supply. Because of the variations in industrial use and in fringe area service, it is obvious that gross per capita figures will vary greatly from city to city. Industrial use is the major distorting influence.

Variation With Population--A study of the records of 20 selected cities for the period 1940-1956 has furnished data on per capita use. These curves show present per capita use to be about 85 gallons per day for cities of around 10,000 population, 120 gallons for populations of about 20,000, and 135 gallons for cities with 30,000 people. Chattanooga, with a 1955 population of over 100,000 has a daily per capita use of about 150 gallons. The U. S. Geological Survey, in a report on the 1955 use of water, estimated per capita use from public supplies in the combined Tennessee and Cumberland River basins at 148 gallons per day.[2]

Variations in Seasonal Demand

Pumpage records for the 20 selected municipalities in the Valley show that the lowest monthly average demand for water usually occurs in March and the highest in August. In 1956 the August municipal water use in the 20 cities was 119 percent of the annual mean and the March use was 90 percent. This seasonal spread has increased steadily since 1940. Monthly use of water is

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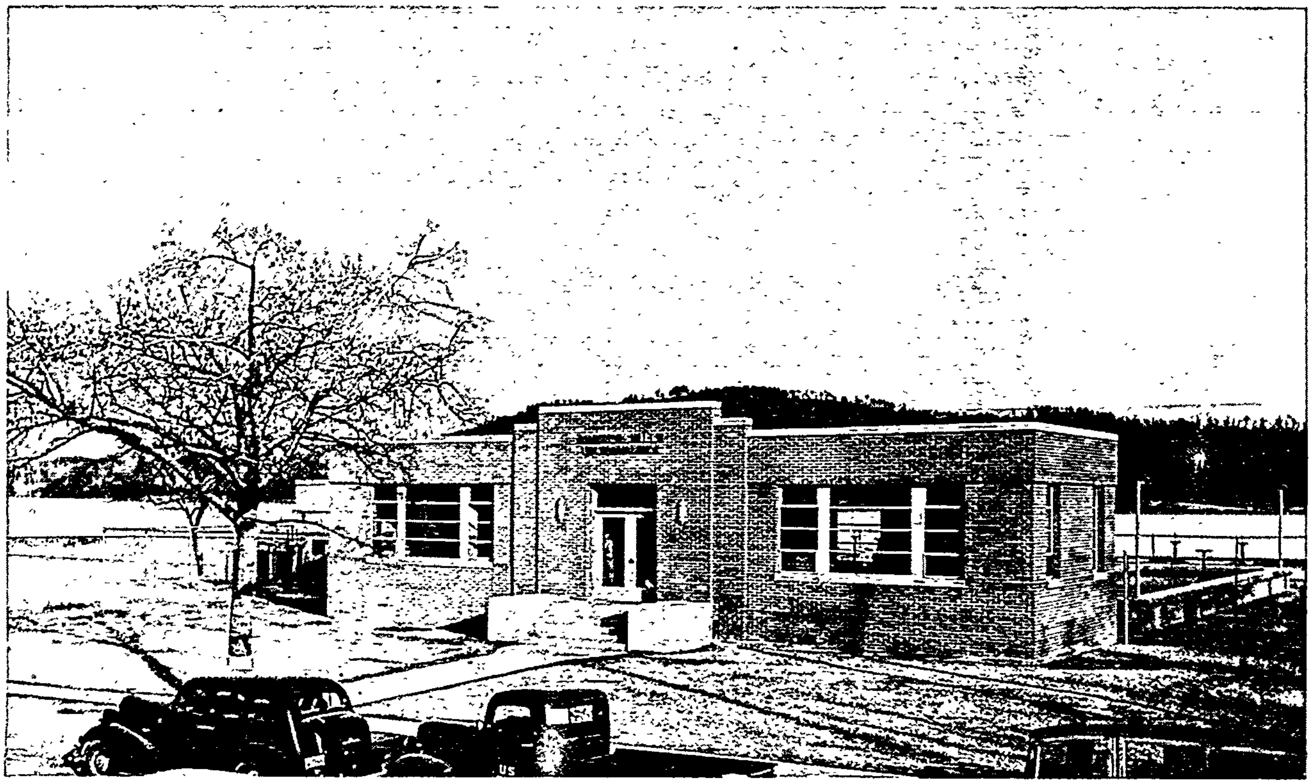
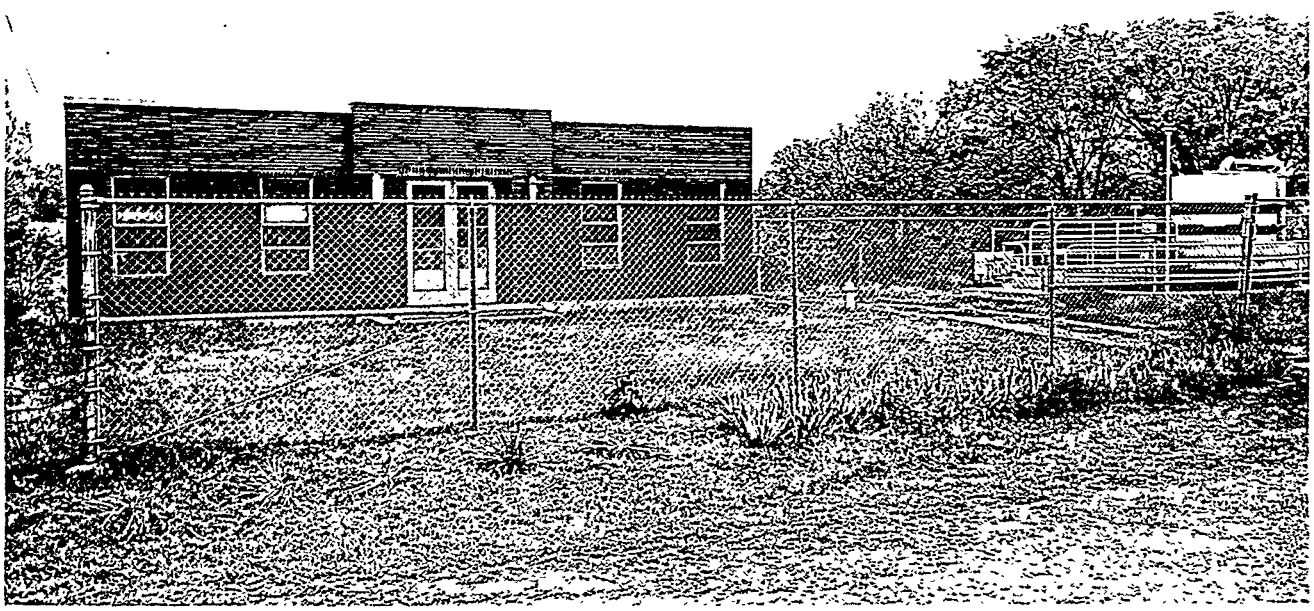
2. Geological Survey Circular 398, "Estimated Use of Water in the United States, 1955." By Kenneth A. MacKichan, Washington, D. C., 1957.



The Guntersville, Alabama, Municipal Water System takes its supply from the nearby TVA reservoir.



Jefferson City, Tennessee, is supplied by a large spring about three miles from the city.

usually above the 12-month average in June through September and below the average the rest of the year. High use in the summer results from seasonal activities such as watering gardens and lawns, washing cars, and filling swimming pools.

Of importance in this seasonal variation is (1) that the peak municipal use comes one or two months prior to the occurrence of minimum streamflow, and (2) that the highest municipal use coincides with the highest irrigation use.

Peak Days

Using the records for the 20 selected cities, a study was made of the ratio of the water use on the peak day of each month to the monthly average. The data showed that this ratio remains about the same from month to month in a year and that there has been no long-term change during the past 17 years.

There is a strong correlation, however, between population served and this ratio of peak daily use to monthly average use. In large cities the peak day use is but little greater than the monthly average; in small systems the peak day may be 50 percent or more above the monthly average.

Effects of Metering

Unmetered water distribution systems are common where water is plentiful and the expense of operation is small. This is especially true where water is supplied to the municipal system by gravity from an uninhabited catchment area high in the mountains with no pumping or treatment expense. The customers of such a system are usually billed a fixed amount monthly regardless of the quantity of water they use.

Tullahoma Experience--A striking reduction in municipal water use usually follows the installation of meters. At Tullahoma, Tennessee, a rapidly increasing population was causing an extremely rapid rise in municipal water use and was overloading the filter plant. By installing meters during the winter of 1951-1952 the city delayed the need for an expansion in the treatment plant by some five years even though population continued to climb.

Present Municipal Water Use

In table 17 the volume of surface water and ground water used by municipal systems that served populations of 1,000 or more in 1955 is summarized for each of the 10 major drainage basins of the Valley. The data in the table represent about half of the systems in the region but about 95 percent of the water used by municipal systems. Assuming that the 170 systems not included furnish average populations of 500 with 100 gallons of water per capita daily, the total pumpage by these small systems would be roughly 8 million gallons daily or 9,000 acre-feet annually. This would increase the Tennessee Valley totals shown below to approximately 156 million gallons per day or 175,000 acre-feet.

TABLE 17

SUMMARY OF MUNICIPAL WATER USE IN 1955

(Systems Serving Populations of 1,000 or Over)

Drainage Basin[a]	Average Daily Use Million Gallons			Annual Use Thousand Acre-Feet		
	Surface Water	Ground Water	Total	Surface Water	Ground Water	Total
Tennessee River - Mouth to Pickwick Dam	5.48	2.55	8.03	6.15	2.85	9.00
Duck River	5.53	0.12	5.65	6.19	0.14	6.33
Tennessee River - Pickwick to Guntersville Dam	10.43	7.14	17.57	11.67	8.00	19.67
Elk River	1.93	0.10	2.03	2.16	0.11	2.27
Tennessee River - Guntersville Dam to Knoxville	62.77	2.46	65.23	70.32	2.74	73.06
Sequatchie-Emory Rivers	1.23	0.00	1.23	1.38	0.00	1.38
Hiwassee-Little Tennessee Rivers	3.89	0.30	4.19	4.36	0.34	4.70
Clinch River	7.66	0.08	7.74	8.58	0.09	8.67
Holston River	19.26	0.51	19.77	21.58	0.57	22.15
French Broad River	16.50	0.10	16.60	18.48	0.11	18.59
Tennessee Valley	134.68	13.36	148.04	150.87	14.95	165.82

(a) See figure 6 for location.

Water Use in 1975

Water use in municipalities of the Valley has increased rapidly in the past 17 years as a result of increased urban population and larger per capita use. Much valuable information that can be used in estimating trends for the future has been obtained from the unusually good records of water use for the 1940–1956 period maintained by 20 well-distributed water systems over the Valley. These systems serve populations ranging from 1,500 to 220,000.

The per capita water use trend lines approximated from these data show an increase in per capita use by 1975 of about one and one-half times the present use. The values adopted for this study are somewhat lower than many being used for design purposes at the present time. The data also indicate that the August high month use in 1975 will be about 135 percent of the annual mean month as compared to the present 119 percent. The March low month use will drop from the present 90 percent to 85 percent of the mean month.

Using these data on trends in municipal water use, together with predictions of population growth, the 1975 use has been predicted for each municipal system serving 1,000 or more population. These predictions are summarized by 10 major drainage basins in table 18. No attempt has been made to estimate the ground-water use but with increased loading on municipal systems this will undoubtedly be even smaller in proportion than at present. Water use by municipal systems serving less than 1,000 people will probably add another five percent, making a Valley total municipal use for 1975 of about 270 million gallons per day or about 300,000 acre-feet. This is roughly 170 percent of the 1955 municipal use.

TABLE 18

SUMMARY OF PREDICTED MUNICIPAL WATER USE IN 1975

(Systems Serving Populations of 1,000 or Over)

Drainage Basin[a]	Average Daily Use in Millions of Gallons	Annual Use in Thousands of Acre-Feet
Tennessee River - Mouth to Pickwick Dam	13.91	15.58
Duck River	10.29	11.53
Tennessee River - Pickwick to Guntersville Dam	38.53	43.16
Elk River	3.67	4.11
Tennessee River - Guntersville to Knoxville	108.49	121.52
Sequatchie-Emory Rivers	2.13	2.39
Hiwassee-Little Tennessee Rivers	6.26	7.01
Clinch River	12.67	14.19
Holston River	35.40	39.65
French Broad River	23.85	26.72
Tennessee Valley	255.20	285.86

(a) See figure 6 for location.

INDUSTRIAL WATER SUPPLIES

The economic well-being of any region is closely related to the continued growth of its industry. The abundance of high quality water in the Valley has been a principal factor in the phenomenal industrial expansion that this area is experiencing, and it marks the region as one of the most desirable for future industrial development in the nation.

Characteristics of Use--The use of water by industry is a withdrawal use. Water quality requirements are variable, ranging from stringent to lenient. Quantity requirements in the so-called "wet" industries are very high. Consumption of the water used is low, averaging about five percent of the total use. Pollution is the principal source of conflict with other uses.

Sources of Water

Many industries use several sources of water simultaneously. It is quite common for a single industry to obtain potable water from a municipal system, cooling water from an adjacent stream, and process water from a well drilled on the plant grounds.

Economy is the ruling factor in choice of a source of water. In locations with reasonable municipal water rates, consistently satisfactory water treatment, and adequate reserve capacity, industries are inclined to use municipal systems for process water. At Chattanooga, for example, 190 industries buy 16 million gallons of water per day from the private utility serving the area. They also pump 10 million gallons daily from wells, and take about 2 million gallons a day from the Tennessee River or tributary streams. At Columbia, 12 industries consume 1.5 million gallons of water per day of the 2.5 million gallons that the municipal filtration plant produces.

Surface water is used by industry when huge volumes are required. Ground water is used to avoid filtration, or when the uniform low temperatures are advantageous for cooling purposes.

Water Uses

Industrial use of water can be divided into five classes which are discussed below.

1. Fire protection--Although rarely used, the capacity of industrial fire systems is often larger than any other except that for heat transfer. The municipal supply is generally used.

2. Potable water--In the "dry" industries, this and fire protection are the major uses. Municipal supplies are the usual source.

3. Heat transfer--In this use, raw water is piped through a condenser or some other heat transfer device to remove heat from the process liquid. In the Valley, where water is normally abundant, surface water is used, and it is usually returned to the stream with the only pollution being increased temperature.

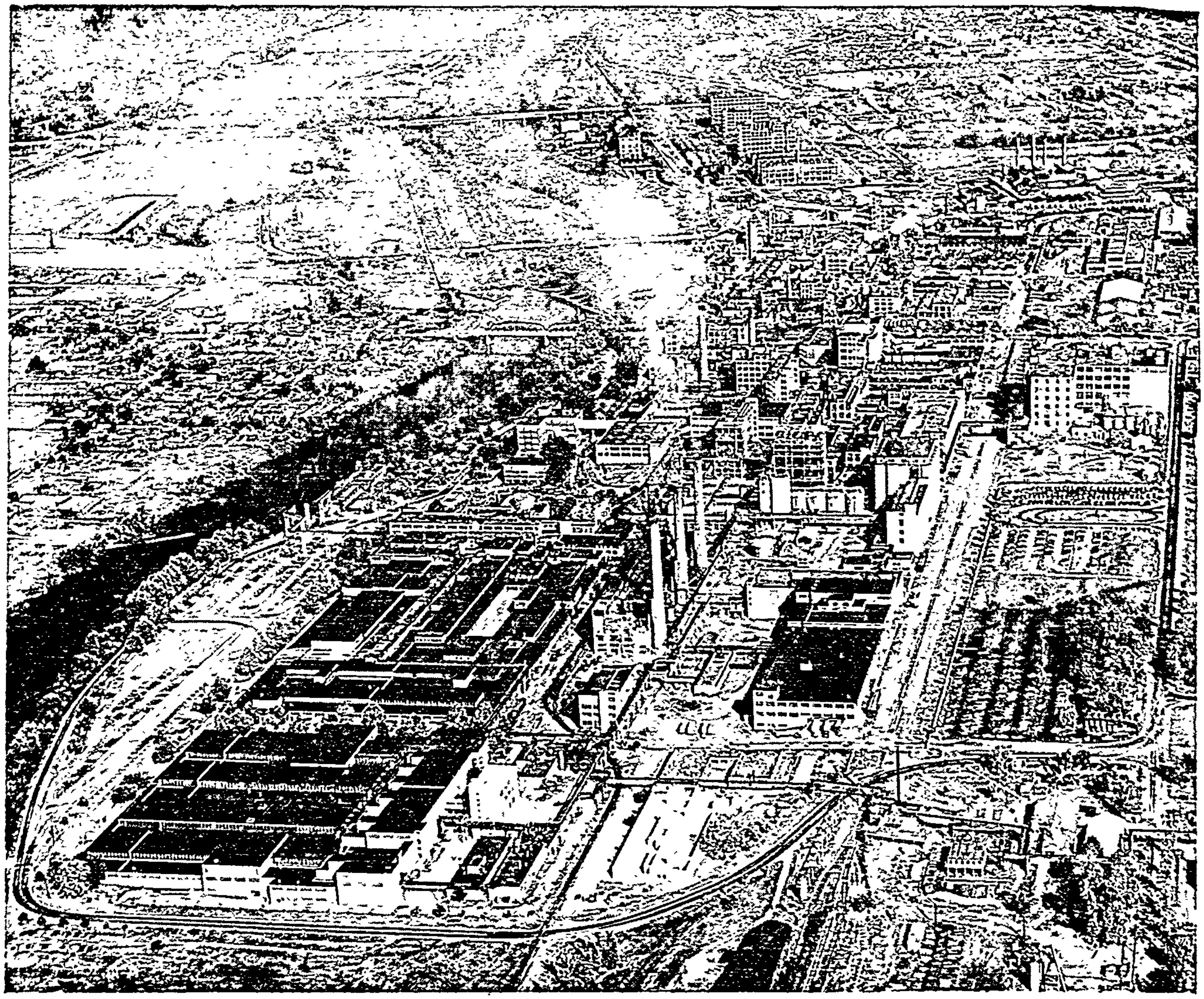
4. Boiler make-up--Many industries in the Valley require steam for their processes or for heating. Very little power is generated by steam in Valley industry. Because boiler make-up water requires considerable treatment, recirculation is practiced wherever possible.

5. Process water--In the manufacturing process, water may be used (a) as a vehicle to transport the product through the process, as in paper making; (b) for washing and removal of impurities, as in wool scouring; (c) for bringing the various components into contact, as in tanning of leather; (d) as a chemical component of the reaction in which the product is formed, as in production of sulfuric acid; and (e) as an integral part of the product, as in bottling and food canning.

Quality Requirements

Although almost any fresh water can be treated to make it suitable for almost any industrial use, the dictates of economy require that the quality of the raw water be as close to that of the finished water as possible. Constituents most often found objectionable to industry are: iron and manganese, hardness, turbidity, color, taste or odor, and high temperature. Industries manufacturing textiles, paper, plastics, and soft drinks have very strict requirements as to iron and manganese, turbidity, and color.

Fortunately, the wide range of geologic conditions on the Tennessee Valley provides water of varying mineral content, so that industries have the opportunity of building plants in locations where the water best suits their needs. The waters of the southeastern mountain region of the Valley are especially favorable to the critical needs of paper and textile manufacturers.



Industrial Area of Kingsport, Tennessee

Kingsport, situated on the South Fork Holston River, is an important industrial center. Four TVA hydroelectric projects, Watauga, South Holston, Boone, and Fort Patrick Henry, are located in the river basin upstream from the city. The Tennessee Eastman Company, in the foreground, uses large quantities of the river water to produce acetate rayon.

Quantity Requirements

The amount of water used in the manufacture of a specific product varies with the availability of water, plant design, operational efficiency, and even with the color of the product. Light colored papers, plastics, and textiles require more water and allow less recirculation than darker colored products.

Paper and Fiber Plants Heaviest Users--Fifty percent of all industrial water used in the Valley is required to supply seven large paper mills and seven large synthetic fiber plants, all but two of which are located east of Chattanooga. Table 19 lists these major industrial water users and the products they produce. The synthetic fiber plants in this group use a total of 260 million gallons per day, while the paper mill use is close to 100 million gallons per day. Expansion is under way or has recently been completed on the plants at Calhoun, Canton, and Kingsport. A new paper mill on Kentucky Reservoir has been proposed, and a doubling of the capacity of the acrylic fiber plant near Decatur is planned.

TABLE 19

MAJOR INDUSTRIAL WATER USERS IN TENNESSEE VALLEY

Company	Location	Product
Synthetic Fiber Plants		
Chemstrand Corp.	Decatur, Ala.	Acrylic fiber
American Enka Corp.	Enka, N. C.	Viscose rayon
American Enka Corp.	Lowland, Tenn.	Viscose rayon
American Bemberg Corp.	Elizabethton, Tenn.	Cuprammonium rayon
North American Rayon Corp.	Elizabethton, Tenn.	Viscose rayon
Tennessee Eastman Corp.	Kingsport, Tenn.	Acetate rayon
E. I. duPont de Nemours & Co.	Chattanooga, Tenn.	Nylon
Paper Mills		
Champion Paper Fibre Co.	Canton, N. C.	High grade white paper
Ecusta Paper Co.	Pisgah Forest, N. C.	Cigarette paper, cellophane
Mead Corp.	Sylva, N. C.	Corrugating board
Mead Corp.	Harriman, Tenn.	Corrugating board
Mead Corp.	Kingsport, Tenn.	High grade white paper
Southern Extract Co.	Knoxville, Tenn.	Corrugating board
Bowaters Southern Paper Co.	Calhoun, Tenn.	Newsprint, Sulfate pulp

Present Water Use

The diversity of water sources used by industry, the lack of quantitative records or metering, and a natural reluctance of industry to divulge process information combine to make data on the industrial use of water less plentiful and less reliable than on municipal use. However, a rather complete estimate of the present use has been obtained from state agencies and the industries themselves. Table 20 summarizes the industrial use in the ten major drainage basins. The data in table 20 do not include or duplicate the purchase of water by industry from municipal systems which was included in table 17.

TABLE 20

INDUSTRIAL WATER USE IN 1955 AND PREDICTED USE IN 1975

(Not Including That Obtained Through Municipal Systems)

Drainage Basin[a]	1955 Million Gallons Per Day	1955 Thousand Acre-Feet	1975 Million Gallons Per Day	1975 Thousand Acre-Feet
Tennessee River - Mouth to Pickwick Dam	30.2	33.8	60.5	67.8
Duck River	46.1	51.6	69.1	77.4
Tennessee River - Pickwick to Guntersville Dam	29.6	33.2	59.2	66.3
Elk River	27.1	30.4	40.2	45.0
Tennessee River - Guntersville to Knoxville	47.0	52.6	94.0	105.3
Sequatchie-Emory River	3.5	3.9	5.3	5.9
Hiwassee-Little Tennessee River	50.5	56.6	76.3	85.5
Clinch River	11.0	12.3	16.5	18.5
Holston River	307.0	343.9	408.0	457.0
French Broad River	98.3	110.1	147.4	165.1
Tennessee Valley	650.3	728.4	976.5	1,093.8

(a) See figure 6 for location.

A comparison of these volumes with those listed in table 17 shows that the industrial use substantially exceeds the municipal use in all areas except the upper reach of the Tennessee River which includes both Chattanooga and Knoxville. There are only three municipal systems in the Valley with an average use of more than 10 million gallons per day. The largest system uses slightly over 30 million gallons daily. In contrast, 11 industrial systems in the Valley use over 10 million gallons per day and the largest one pumps approximately 200 million gallons per day—more than all of the municipal systems combined.

Comparison with Census Data--A Census of Manufactures tabulation of water use by industry in the Tennessee Valley counties in 1954 showed a grand total intake of 262 billion gallons or 800,000 acre-feet. Table 20 shows a total of 728,000 acre-feet. Most of the difference of approximately 10 percent is probably the industrial water obtained through municipal systems. The Census figures also show that, of 800,000 acre-feet taken into the plants, some 750,000 acre-feet or 94 percent was discharged.

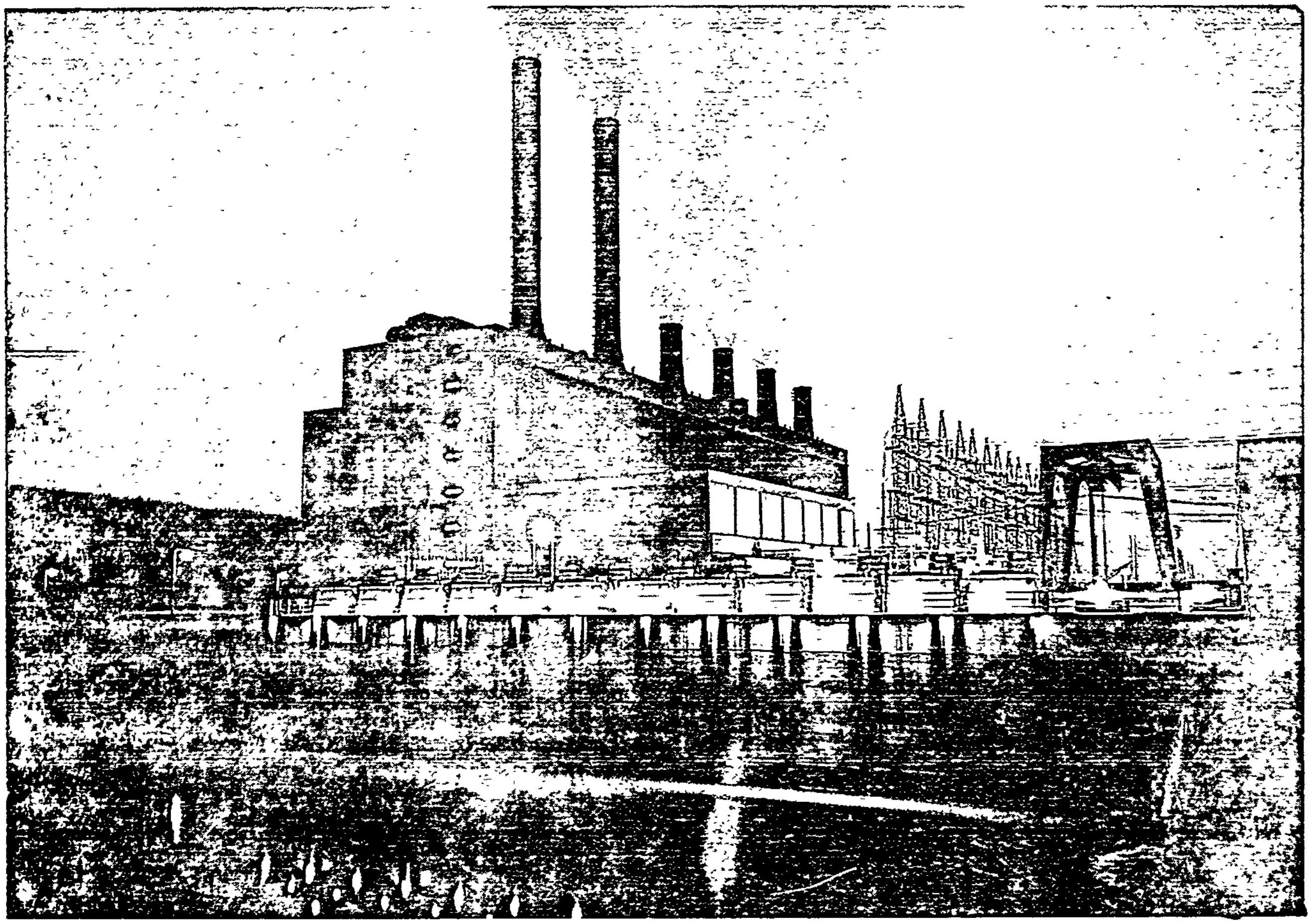
Water Use in 1975

Table 20 also shows an estimate of the probable industrial use in each of the 10 major basins in 1975. The rather erratic development pattern of industry and the lack of water use records over the years makes a prediction of future water use difficult. The predictions made for this study are based on knowledge of the construction now under way, planned expansion, and proposed new plants, together with information on the availability of water in each area. The largest percent of increase in industrial water use is expected along the Tennessee River. The percentage increase in industrial use from 1955 to 1975 in the Tennessee Valley is expected to be approximately 50 percent. This compares with the 70 percent increase expected in municipal use in the same period.

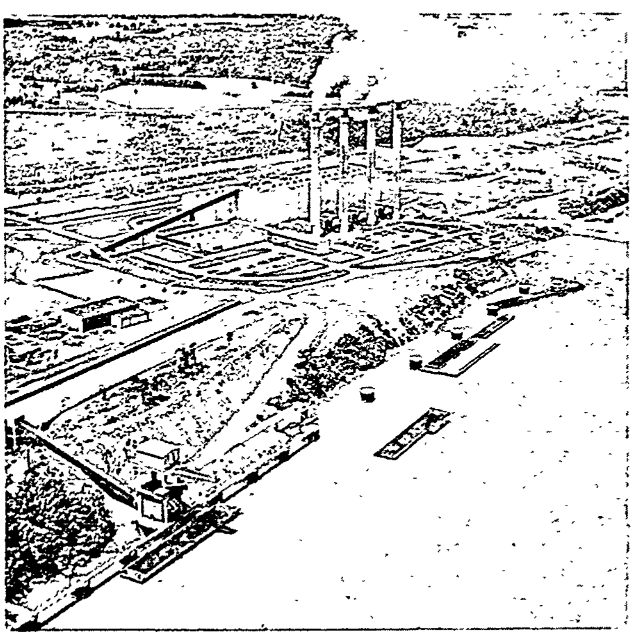
STEAM POWER GENERATION

Some classifications list the water used by large central station steam-electric plants as an industrial use. Steam plant use, when carried on as part of an industrial operation, properly belongs in the industrial grouping. However, to include the TVA steam-electric plants with industry in general would seriously distort and obscure the industrial use picture, since this group of plants utilizes 7 or 8 times as much water as the rest of the Valley industry combined. For this reason the strictly steam-electric use in the Valley has been given a separate listing in the classification for this study.

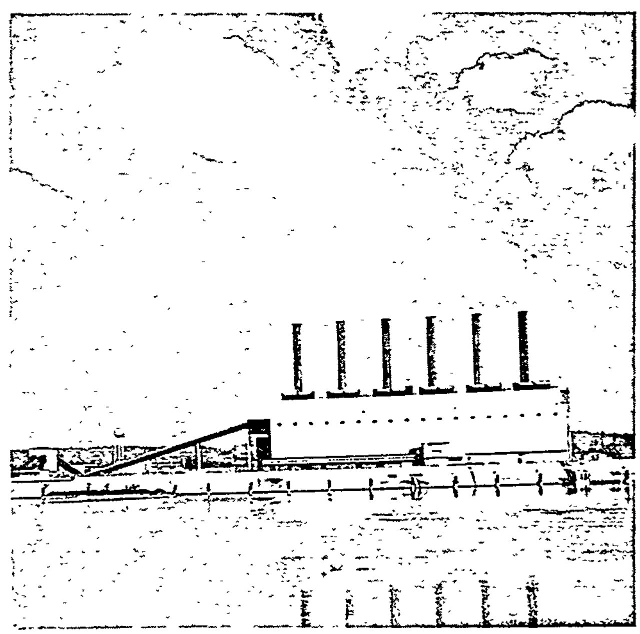
Characteristics of Use--Water use for steam power generation is a withdrawal use. Quality requirements for more than 90 percent of the use



Widows Creek on Guntersville Lake.



Colbert on Pickwick Lake.



Johnsonville on Kentucky Lake.

All but one of TVA's larger steam-electric generating plants within the Valley boundaries are located on Tennessee River reservoirs.

are low. Quantity requirements are very large. Water losses are negligible in the type of operation generally carried out in the Valley. Some pollution results from the use in that the released condenser water may be 10 to 18 degrees warmer than the original supply. Also surface runoff from coal storage areas may at times pollute streamflow locally.

Source of Water

The very large quantities of water needed for economical operation of steam plants demands that the plants be located adjacent to considerable surface water supplies. In the Tennessee Valley, four of the five largest plants are located on Kentucky, Pickwick, Guntersville, and Watts Bar Reservoirs. The fifth, situated on the Holston River which is regulated by storage above, is further insured against shortages by a water supply reservoir on the river. The lesser plants are located either on reservoirs or on regulated streams.

Cooling Towers and Ponds--An alternative to a location near large surface water sources is the provision of cooling towers or ponds. The greater initial cost and higher operating and maintenance cost of these methods of cooling as compared to surface water use have so far discouraged their general adoption in the Valley. However, one large plant using cooling towers has recently been completed by the Appalachian Power Company on the upper reaches of the Clinch River near Carbo, Virginia, where discharges are not sufficient for large scale cooling by surface water. Evaporation and other losses in this type of plant would amount to one to two percent of the water used.

Water Uses

Practically all of the water used at steam plants is for condenser cooling. Minor uses at the plants include water for boiler feed, cooling generator hydrogen and bearing oil, drinking water and sanitation, air conditioning, fire protection, dust-control operations, and sluicing ashes.

Quantity Required

The larger TVA steam plants require quantities of water equivalent to the normal flow of a good-sized river. The Kingston plant, for example, uses 2,150 cubic feet per second of condensing water, slightly greater in amount than the average annual discharge of such streams as the French Broad River at Asheville, North Carolina, the Clinch River above Tazewell, Tennessee, or the Duck River at Columbia, Tennessee. John Sevier plant, the smallest of the five large TVA plants, uses as much water through its condensers as the average annual flow of Nolichucky River at Poplar, North Carolina, or Little Tennessee River at Needmore, North Carolina.

Quality Required

The scale-forming minerals usually present in surface water do not affect condenser tubes because the temperatures remain relatively low. The tubes are large enough in diameter so that ordinary suspended sediment does not clog them. Condenser cooling water is treated with chlorine at Kingston and John Sevier Steam Plants to kill slime organisms that form on condenser tubes. This growth interferes with flow in the tubes and acts as an insulator, thus reducing the efficiency of the units.

Boiler feed water must be of high quality. This water comes from two sources: (1) steam condensed at the end of the cycle and returned to the boiler, and (2) makeup water from outside sources. The latter must be treated to remove as much as possible of the carbonate, calcium, magnesium, and sodium ions, and other impurities.

Water Temperature

The temperature of the condenser water supply is likely to be more important than its quality. The efficiency of the condenser varies with the mean temperature difference between the steam and the condenser water. A rise of a few degrees is reflected in lowered efficiency of the turbogenerator. Cooling water intakes for TVA steam plants are installed with great care to provide the coolest water. Where necessary, underwater dams and skimmer walls are built to divert cool water into the intakes and to exclude warm water.

Effect of Steam Plant Use on Water Temperature

The temperature of water used for condensing in one of TVA's large steam-generating plants is normally increased about 10 to 12 degrees as it passes through the plant. This heated water, when returned to the river or reservoir from which it was taken, causes some local heating for a short distance above the discharge point and for a longer distance below. The extent of this warming will vary somewhat at each plant. Generally, however, the effect will not be felt for more than one-half mile upstream or for more than two or three miles downstream from the plant. Heating will be more pronounced on the side of the river or reservoir into which the discharge is made, but the effect may be noticeable across the entire width of the reservoir under certain circumstances. The depth to which the warming extends will vary with location and season of the year. In general, the depth of warm water flow will be greater on the steam plant side of the reservoir.

Present Water Use

The annual volume of water used by the Tennessee Valley steam plants varies with streamflow conditions at the hydro plants and the corresponding hydrogeneration available. In a year of average flows the plants under present load conditions will use about 5.3 million acre-feet of condenser water. In a dry year when more steam generation is needed to meet the load, the steam plants will require some 6.1 million acre-feet, equal to the total volume of Kentucky Reservoir. For comparison, the present irrigation use is about 20,000 acre-feet, the present municipal use is about 175,000 acre-feet, and the industrial use is roughly 730,000 acre-feet.

Table 21 lists the annual condenser water use for each of the present steam plants under average year and dry year conditions. The total of all water uses by the plants would be only slightly larger than the values shown.

TABLE 21

CONDENSER COOLING WATER USE AT TENNESSEE VALLEY STEAM PLANTS

Plant	Water Source	Water Use - Acre-Feet	
		Average Year	Dry Year
Johnsonville	Kentucky Reservoir	1,020,000	1,020,000
Colbert	Pickwick Reservoir	735,000	920,000
Wilson	Pickwick Reservoir	14,200	113,600
Widows Creek	Guntersville Reservoir	794,000	993,000
Hales Bar[(a)]	Hales Bar Reservoir	6,400	64,400
Watts Bar[(a)]	Watts Bar Reservoir	181,000	406,000
Kingston	Watts Bar Reservoir	1,560,000	1,560,000
John Sevier	Holston River	660,000	733,000
AEC	Clinch River	320,000	320,000
Clinch River	Clinch River	15,000	15,000
Total		5,305,600	6,145,000

(a) These two plants draw water from the reservoir and discharge below the dam.

Water Use in 1975

It is expected that the load on the TVA generating system in 1975 will be more than double that of 1957. Since the largest and most favorable hydroelectric sites have already been developed, this great increase in power requirement will necessarily be met principally by fuel-electric generation. The exact location of the new steam plant sites must be governed by conditions existing at the time their need is established, but the general location and water needed can be estimated.

The trend in water use for steam plants is toward a more efficient use of condensing water. This trend could result in (1) larger installations at sites now limited by water supply, (2) more consideration of cooling towers and cooling ponds, and (3) more flexibility in selecting locations for steam plants.

Table 22 lists by states within the Tennessee Valley the volumes of water that would be required in 1975 to operate the expanded steam plant system. The total use shown by the table is some three and one-half times the present use.

TABLE 22

ESTIMATED STEAM PLANT WATER REQUIREMENTS IN 1975

Location in Valley	Estimated Water Use in Acre-Feet
Kentucky	760,000
Alabama	8,100,000
Tennessee	12,000,000
Total	20,860,000

MINING OPERATIONS

The use of water for mining operations has been considered separately in this study from that for industry in general. Certain aspects of this use are different from industrial use. The Bureau of the Census also separates mining operations from industry generally.

Characteristics of Use--This is a withdrawal use. Quality requirements are low. Total quantities involved are relatively small in the Valley. Because of certain evaporative processes the consumptive use in mining operations is fairly high, averaging about 25 percent of the total use. Conflicts result from the discharge, in some instances, of mine tailings back into the stream. In one instance, on the Nolichucky River in Tennessee, two-thirds of the storage capacity of a power reservoir has been lost principally from tailings from upstream mining operations which have been deposited in the reservoir. The municipal water supply at Greeneville has been adversely affected by color and turbidity from these operations.

Types of Operations

Mining in the Valley is concentrated in several limited areas. Phosphate rock is mined in the Nashville Basin portion of the Duck and Elk River drainages. Iron ore is mined in northern Alabama, principally in the Bear Creek basin. Marble is quarried in the Knoxville vicinity and near Murphy, North Carolina. A substantial zinc mining operation is carried on in the lower Holston River basin, and manganese is mined in the upper portion of that basin. Mica and feldspar are the principal mined materials in the French Broad River basin. Barites are mined near the mouth of the Little Tennessee River and copper in the central part of the Hiwassee basin. Coal is mined in the upper Clinch River basin.

In most of these operations water is taken from surface streams. A few use wells or utilize seepage water pumped from the mines.

Use Made of Water

In the mining and milling of ores and solid fuels and in the quarrying or rock, water is used in the following ways:

Hydraulic stripping of overburden.

Wet drilling.

Dust control.

Ore washing, or concentrating ore by washing out clay, chert, and other impurities.

Flotation and heavy-media method of ore concentration.

Sawing and polishing marble.

Quenching furnace products.

Cooling bearings and engines.

Potable water and sanitary purposes.

The ore washing and flotation uses involve the heaviest use of water at mining operations in the Valley. Little hydraulic stripping is carried on.

Consumptive Use--Little information is available on the losses of water to evaporation involved in the mining operations. Considerable amounts are evaporated in the washing of ground mica. Mines report 20 to 30 percent moisture in the wet mica before it is sent to the kilns and a 5 to 12 percent decrease between intake and discharge pumpage. Feldspar flotation process losses run from one to seven percent at the few mines that reported intake and discharge flows. Water used in dust control, drilling, sawing, polishing, and similar operations is probably all lost. Considerable evaporation occurs where water is lagooned to settle out waste materials.

For the purpose of this study, consumptive use in the mining operations has been estimated at an average of 25 percent.

Present Water Use

Water use data have been obtained from a sampling of 60 percent of the mining operations in the Valley. From these data the volumes of present use in each of the 10 drainage basins have been estimated and are shown in table 23.

TABLE 23

SUMMARY OF MINING OPERATION WATER USE IN 1956

Drainage Basin[a]	Principal Mining Operation	Volume Used Thousand Acre-Feet
Tennessee River - Mouth to Pickwick Dam	Clay	0.3
Duck River	Phosphate	17.0
Tennessee River - Pickwick to Guntersville Dam	Iron Ore	2.9
Elk River	Phosphate	1.3
Tennessee River - Guntersville Dam to Knoxville	Marble	0.2
Sequatchie-Emory Rivers	-	0.0
Hiwassee-Little Tennessee Rivers	Barites, mica	1.5
Clinch River	Zinc, coal	0.6
Holston River	Zinc, manganese	7.0
French Broad River	Mica, feldspar	13.0
Tennessee Valley		43.8

(a) See figure 6 for location.

Water Use in 1975

Some shift in mining operations is expected in the next few years. The present manganese operations will probably decrease in importance. There are indications of a substantial growth in heavy minerals operations, such as titanite, rutile, zircon, and ilmenite.

It is estimated that the increase in water use will be approximately 50 percent over the 1956 use, or a Valley total of 65,000 acre-feet. No data are available to allocate this increase by drainage basins.

SUMMATION OF USES

The "moment of truth" in a basin-wide study of water resources comes when the accumulated and ever-expanding uses are compared with the fixed resource. Questions which caused the study to be made now should be answerable. Do important shortages of water exist? Are they imminent? What conflicts exist or threaten? Can they be resolved? Does remedial action need to be taken soon, or is a program of watchful vigilance sufficient? Does new legislation need to be enacted to protect the essential uses, or are the existing laws satisfactory?

Summation of Present and Future Uses

When a summation of the water uses described previously is compared with the water available there appears to be no wide-spread shortage of water in the Tennessee Valley at present and none seems to be threatening the region in the next 15 to 20 years. There are, however, problems of seasonal water shortages existing now on relatively small areas as a result of heavy consumptive use and there will undoubtedly be many more in the future.

Annual Requirements--The data presented in table 24 show the current and 1975 gross annual requirements of water for each use and the estimated quantity of water consumed or taken out of circulation by these uses. Under present conditions this annual consumptive use of water is about 120,000 acre-feet or about one-half of one percent of the total available dry year discharge at the mouth of the Tennessee River. By 1975 the gross use of water will be three or more times larger than it is now but the consumptive use will increase only about 80 percent. In making these broad comparisons of water use against streamflow it must be kept in mind (1) that the supply of water at the actual point of withdrawal upstream is always less than that at the mouth of the river and (2) that a very large part of the annual streamflow volume occurs during floods and is wasted.

Summer Season Requirements Over Valley--Table 25 presents data on withdrawal and consumptive use volumes in each of the months June to September for the six withdrawal uses. Maximum consumptive uses generally occur during the June-September period, along with fairly low flows, making this a critical period in the year. The total present and 1975 consumptive use of water for the four months is compared in the table with the corresponding volumes of water flowing from the mouth of the Tennessee River in a very dry summer season and in an average summer season. This table shows that the margin between consumptive demand and supply is less in these four summer months than for the total year but there is still no indication of a widespread shortage.

Critical Area Needs--The previous discussion of the water resources and water uses in the Valley has suggested that if shortages occur they will be found in the western part of the Valley rather than in the east, and particularly in the Duck and Elk River basins and the Pickwick to Guntersville region of northern Alabama. In table 26, the withdrawal uses in these three areas are tabulated for the four month period June-September. Comparison is made with the dry year and average year streamflow from each area for the same four months. Here again the total of the consumptive uses is considerably less than the total water available.

TABLE 24

SUMMATION OF PRESENT AND FUTURE ANNUAL WATER USES

IN THE TENNESSEE VALLEY

Use	Present Use - Acre-Feet		Predicted 1975 Use - Acre-Feet	
	Gross Annual Requirement	Annual Consumptive Use	Gross Annual Requirement	Annual Consumptive Use
A. In Place Uses				
Recreation	(a)	0	(a)	0
Navigation	(a)	0	(a)	0
Fish & Wildlife	(a)	0	(a)	0
Pollution Dilution	(a)	0	(a)	0
Drainage	(a)	0	(a)	0
B. Regulatory Uses				
Flood control	(a)	0	(a)	0
Navigation	200,000	0	539,000	0
Hydroelectric power	(a)	0	(a)	0
Mosquito control	(a)	0	(a)	0
C. Withdrawal Uses				
Irrigation	20,000	18,000	80,000	72,000
Rural domestic	76,000	38,000	121,000	48,000
Municipal	175,000	17,000	300,000	30,000
Industrial	730,000	36,000	1,094,000	55,000
Steam power	6,000,000	0	20,900,000	0
Mining	44,000	11,000	65,000	16,000
Totals	7,245,000 (b)	120,000	23,099,000 (b)	221,000

Annual streamflow at mouth of Tennessee River -

Dry year (1941)	22,500,000 acre-feet
Average year	47,500,000 acre-feet

(a) Very large but indeterminable quantities of water are needed for these uses.
(b) Total of determinable quantities.

TABLE 25

SUMMATION OF PRESENT AND FUTURE WITHDRAWAL USES

DURING SUMMER SEASON JUNE - SEPTEMBER

Withdrawal Use	Water Used and Consumed - Thousand Acre-Feet[(a)] June	July	August	September	Total
Present Uses					
Irrigation - used	2.0	8.0	6.5	3.0	19.5
consumed	1.8	7.2	5.9	2.7	17.6
Rural domestic - used	7.0	7.5	8.0	7.0	29.5
consumed	3.5	3.8	4.0	3.5	14.8
Municipal - used	14.7	15.3	15.5	14.7	60.2
consumed	1.5	1.5	1.5	1.5	6.0
Industrial - used	61.0	67.0	70.0	61.0	259.0
consumed	3.0	3.4	3.5	3.1	13.0
Steam - used	500.0	500.0	500.0	500.0	2,000.0
Mining - used	4.0	4.0	4.0	4.0	16.0
consumed	1.0	1.0	1.0	1.0	4.0
Total used	588.7	601.8	604.0	589.7	2,384.2
Total consumed	10.8	16.9	15.9	11.8	55.4
Predicted 1975 Uses					
Irrigation - used	8.6	32.6	25.8	12.4	79.4
consumed	7.7	29.4	23.2	11.2	71.5
Rural domestic - used	11.0	11.5	12.5	11.0	46.0
consumed	4.4	4.6	5.0	4.4	18.4
Municipal - used	25.4	26.4	26.6	25.6	104.0
consumed	2.5	2.6	2.7	2.6	10.4
Industrial - used	91.0	100.0	105.0	91.0	387.0
consumed	4.6	5.0	5.2	4.6	19.4
Steam - used	1,750.0	1,750.0	1,750.0	1,750.0	7,000.0
Mining - used	5.0	6.0	6.0	5.0	22.0
consumed	1.2	1.5	1.5	1.2	5.4
Total used	1,891.0	1,926.5	1,925.9	1,895.0	7,638.4
Total consumed	20.4	43.1	37.6	24.0	125.1
Monthly streamflow at mouth of Tennessee River:					
Dry year (1925)	910.4	959.2	542.3	343.3	2,755.2
Average year	2,731.0	2,416.6	1,961.5	1,487.5	8,596.6

(a) Irrigation use is for 1954 rainfall conditions. Other uses are average monthly values increased by an assumed percentage.

TABLE 26

PRESENT AND FUTURE WITHDRAWAL USES

IN THREE CRITICAL AREAS DURING JUNE-SEPTEMBER

Withdrawal Use	Water Used and Consumed - Thousand Acre-Feet Duck River	Elk River	Pickwick-Guntersville
Present Uses			
Irrigation - used	1.0	2.9	5.1
consumed	0.9	2.6	4.6
Rural domestic - used	2.1	2.4	3.2
consumed	1.0	1.2	1.6
Municipal - used	2.3	0.8	7.2
consumed	0.2	0.1	0.7
Industrial - used	19.0	11.2	12.2
consumed	1.0	0.6	0.6
Steam - used	0.0	0.0	90.0
Mining - used	6.2	0.5	1.1
consumed	1.6	0.1	0.3
Total used	30.6	17.8	118.8
Total consumed	4.7	4.6	7.8
Predicted 1975 Uses			
Irrigation - used	8.4	7.8	30.1
consumed	7.6	7.0	27.1
Rural domestic - used	2.8	3.3	5.0
consumed	1.1	1.3	2.0
Municipal - used	4.2	1.5	15.8
consumed	0.4	0.2	1.6
Industrial - used	28.0	16.0	24.0
consumed	1.4	0.8	1.2
Steam - used	0.0	0.0	350.0
Mining - used	9.0	1.0	2.0
consumed	2.3	0.2	0.5
Total used	52.4	29.6	426.9
Total consumed	12.8	9.5	32.4
Streamflow from total area -			
Dry year (1925)	180.3	101.1	263.8
Average year (1956)	265.0	210.0	476.0

CONFLICTS AMONG USES

There are no uses of water that, under certain circumstances, are not in some way competitive with other uses. The principle contributing circumstance is shortage. When there is plenty of water of the proper quality and the proper time and place for each use, there is no competition among the uses. It is only when a use limits quantity, either by consuming the water, by polluting it, or by altering its elevation, that the use becomes competitive with other uses.

In an examination of water use conflicts in the Tennessee Valley as they refer to TVA reservoir operations, it must be recognized that these reservoirs were built and are operated according to the Act primarily for navigation and flood control. The operation for these primary purposes may affect the utilization of water for hydro power generation, recreation, and other uses but it cannot be considered to be in conflict with these uses.

A few of the conflicts that presently exist or that may later develop in the Valley are discussed below. The list is by no means exhaustive.

Recreation

The necessary drawdown of the TVA tributary reservoirs for flood control and power has long been a subject of discussion as to whether it conflicts seriously with recreation. The shoreline becomes remote from recreation facilities as a result of drawdown, and esthetically unpleasing lake beds are exposed, occasionally near the peak of the summer season. However, experience in the Tennessee Valley has shown that this drawdown is not a major factor in the use of these reservoirs for recreation, nor are the needs of sport and commercial fishing or wintering of migratory wildfowl seriously affected by the reservoir fluctuations.

Conflicts between recreation and pollution are lessening in the Valley as more cities treat their sewage, but many still exist as a result of industrial pollution. The French Broad River and some of its tributaries, with a high potential for recreation, have been called "blemishes on the face of a scenic wonderland."[3] The Tuckasegee River, another beautiful mountain stream, is in a similar condition below its junction with Scott Creek. While ample water flows in these streams, a shortage exists as far as the fullest potential recreation use is concerned.

Deaeration in reservoirs conflicts with the pollution dilution use and therefore indirectly with recreation generally.

Drainage conflicts with recreation when marshy areas suitable as fish and wildlife habitats are reclaimed for other uses or to eliminate insect nuisances.

Navigation

This use requires the maintenance of certain depths and flows. Consumptive uses are not likely to affect these requirements in the Tennessee Valley.

Lockages, which necessarily cause water to bypass the turbines, conflict with the production of hydroelectric power.

Sudden releases or shutdowns during flood control and power operations at TVA dams may break an unattended barge loose from its moorings or strand one on the river bank.

Fish and Wildlife

The conflict between this use and drainage of swamps and marshes has already been mentioned. The President's Water Resources Policy Commission called the conflict between drainage and the propagation of fish and wildlife "one of the greatest present conflicts involving our natural resources."[4] It is not as important in the Valley as in other basins where the need for drainage is more widespread.

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3. "Asheville Citizen - Times," October 20, 1957, Section D.
4. A Water Policy for the American People, 1950, Washington, D. C., page 264.

Conflicts between reservoir operation andfish spawning have been pretty well resolved by special TVA water control operations during the short spawning season. However, there are times when the release of deaerated water from the reservoirs has some adverse effect on game fish.

The damaging effect of the release of industrial and urban wastes on game fish is well known. The Buncombe County, North Carolina, Wildlife Club, in a resolution regarding the pollution of the French Broad River stated that "Because of this pollution, the small mouth bass and the mightly muskelunge, native to the Tennessee River basin only in all the southern states, once prevalent in these waters, have been almost entirely eliminated. . . ." In the Pigeon River, another heavily polluted tributary of the French Broad River, fish life is absent from Canton, North Carolina, to Newport, Tennessee. Occasional fish kills occur on the North Fork Holston River as a result of chemical plant pollution.

Impoundments for flood control and power can be both conflicting and compatible with the fish and wildlife use. In the Tennessee Valley the compatibilities among these uses have far outweighed the conflicts.

Pollution Dilution

The use of water to dilute pollution conflicts, for obvious reasons, with uses for recreation, fish and wildlife, urban supplies, and industrial supplies. Only where the pollution is corrosive does it directly affect navigation or hydroelectric power.

The impoundment of water for flood control and power is accompanied by a lowering of the dissolved oxygen content in the lower levels of the reservoirs. Dissolved oxygen is a pollution-absorbing asset. When this water is drawn through the turbines and released below the dams it has less pollution-absorbing capacity than an unregulated flow, at least until it is reaerated. The fluctuations in TVA hydro plant releases, and particularly the week-end shutdown periods, are in conflict with pollution dilution. Impoundment, however, improves the bacteriological quality of the water, settles out sediment, and increases the average low flows. Such increased flows compensate to some degree for the decrease in dissolved oxygen concentration.

Drainage

The conflict of drainage and the use of water for fish and wildlife has been covered under the latter heading.

Hydroelectric Power

Any consumptive use is in conflict with hydroelectric power generation, and particularly those uses that diminish low flow. Between April and December practically all of the water that flows into the TVA system of reservoirs is used through the turbines of one or more hydro plants. Any use that reduces these flows is, therefore, directly competitive.

The impoundment and use of water for power is in several ways beneficial to other users, even to those that are directly competitive. It results in a substantial increase in flow during the dry season for the benefit of navigation and water supplies; the released water is less turbid and of a higher quality than the unregulated streamflow, and water temperatures are lowered. The value of the impoundments for recreation, fish, and wildlife have been mentioned.

Some mining operations conflict with hydro power because they increase the sediment load in the streams. The reservoir above Nolichucky Dam in the TVA system contains so much sediment from the operation of mica mines upstream that a company is "mining" the reservoir for mica. In Polk County, Tennessee, the early smelting operations associated with copper mining have left a large area denuded and eroded to such an extent that reservoirs below it are losing storage space at a rapid rate.

Impoundments with relatively flat shorelines result in a general raising of the water table for some distance back from the reservoir. In many cases this provides larger supplies to domestic wells. In some instances the raised water table may interfere with farming operations.

Flood Control

Flood control's principal conflict in the Tennessee Valley is with hydroelectric power. TVA water control procedures require that, during the flood season, high waters be stored and subsequently spilled to make room for later floods. In some years, a large part of this spilled water could have been used through the turbines and to increase head on the turbines. This is offset in part by the fact that reduction of flows during flood periods aids in preserving capacity at mainstream hydro plants. The reduction in flood heights and frequencies reduces the cost of building and operating waterfront structures, such as river terminals, and makes available more sites for industry.

Mosquito Control

Conflicts between mosquito control and other uses are generally small. The cyclical operation for this purpose imposes some limitation on freedom of operation for hydro power. Only very infrequent wasting of water results from the operation, and the timing of the fluctuations causes little loss of head on the plants.

Irrigation

Irrigation is a source of more potential conflict than other uses because of its high rate of consumption and because this consumption nearly all occurs in the months of June to September when flows are low and other demands are near a peak. Actually, the present annual consumption of water either by industry or by other rural uses is greater than that for irrigation. By 1975 it is estimated that irrigation, because of its high rate of use, will consume annually a greater quantity of water than either of the other two but its consumption will still be only one-third of the total loss. However, by July and August of 1975 it may account for over 60 percent of the total consumptive use over the Valley in each of those months, assuming dry year conditions.

The value of the irrigation water diverted from hydro power use varies widely with the place of application. An acre-foot lost to evapotranspiration on a farm near Franklin, North Carolina, would have produced about 1,080 kwh over 1,235 feet of head, while an identical amount lost near Columbia, Tennessee, would have passed over less than 60 feet of head, producing approximately 40 kwh.

Irrigation and municipal water use are directly competitive. Both uses often take water from small streams or from larger streams with a poorly sustained summer flow. At Columbia, Tennessee, where there is a high municipal and industrial demand and only a small volume of water available, the possible development of upstream irrigation along with the normal increase in municipal and industrial requirements poses a serious problem. Critical shortages could occur on the same river at Shelbyville and Lewisburg. Pulaski, Tennessee, which obtains its water from Richland Creek, could also experience a shortage if its needs increase and irrigation in Giles County continues to expand. A number of other medium-size cities in the Valley are in the same situation.

Irrigators, of course, are in competition with other irrigators on the same stream. In more than one case they have had to substitute cooperation for competition in order that all might benefit from a limited supply.

Rural

The rural use, as defined for this study, includes not only the domestic use in rural homes but also the use of water for stock watering. With these inclusions it becomes a larger and more consumptive use, under present conditions in the Valley, than irrigation. Assuming a 50 percent consumption factor, which may be low, the rural use consumes twice as much water now as irrigation. The rural uses are individually small, widely diversified, and very essential, and they do not attract the adverse attention in competitive situations that the larger individual withdrawals for irrigation do. Most of the water is taken from wells which does not seem to other users to be as directly competitive as water pumped from a surface stream.

Municipal

The municipal conflicts have largely been covered in the previous discussion. The greatest conflict is with the consumptive uses. Water can be treated when it is polluted but it can't be replaced when it is taken away. Impoundment of surplus flow is one possible solution to this problem.

Impounding of water for municipal use sometimes is in conflict with recreational use of the catchment area or of the reservoir. It is an economy to restrict access to these areas because of the higher treatment costs that would be required if they were opened to such recreational activities as fishing and swimming.

Industrial

Many of the smaller industries obtain water through municipal systems and are directly concerned in any conflicts with municipal use. The larger "wet" industries which use much water but consume little, have an adverse effect on municipal use because of their pollution of the streamflow. Much can be done by the cities with treatment, at a price, but there is a limit to the pollution load that water supply treatment plants should be expected to handle.

The pollution resulting from industrial use creates conflicts also with irrigation, recreation, fish and wildlife and with other industry. Industrial pollution of the North Fork Holston River and the Pigeon River, for example, seriously limits the use of these streams by any other industry.

Steam Power

Steam power generation, as presently carried out by all but one plant in the Tennessee Valley, uses great quantities of water but consumes very little. The condenser water, as it is returned to the stream, may be 10 or 12 degrees warmer than the water entering the plant. This pollution quickly corrects itself farther down the stream but it may have some effect on aquatic life or on other use of the water immediately below the plant.

Mining Operations

These operations conflict only to the extent that they pollute the streams with sediment. In some cases this has been serious.

CHAPTER 5

OPPORTUNITIES FOR FUTURE ACTION

CHAPTER 5

OPPORTUNITIES FOR FUTURE ACTION

OPPORTUNITIES FOR EXTENDING AVAILABLE RESOURCES

In the movement of water through the hydrologic cycle, little can be done within the limits of present knowledge to change the total amount of water that reaches the surface of the Tennessee Valley annually. However, steps can be taken to make more of this water available to users in the Valley at the time and place of need. Among these measures are (1) increasing the efficiency of water use, (2) providing impoundments for storage of surplus water and regulation of flow, (3) abating pollution, (4) controlling water on the land, (5) reclaiming sewage effluent, (6) modifying the weather, and (7) converting salt or brackish water to fresh water. All of these means are expensive.

Salt water conversion is not pertinent to the Valley region, and the need to reclaim sewage effluent does not seem pressing. The degree to which the other means may be used in the Valley will depend upon the development of local area shortages and conflicts and the need to spend money to save water.

Increasing Efficiency of Use

When an industry, municipality, or other user is faced with an impending shortage of water, one of the choices open is to stretch the available supply by improving water-use efficiency. When water is cheap and plentiful, waste is apt to be high and efficiency of use is low. Previously cited in this report was the experience of Tullahoma, Tennessee, which added five years to the useful life of its treatment plant by metering its consumers and charging for water used. It has been estimated that unmetered municipal systems use twice as much water per capita as metered systems.

Savings at Steam Plants--Steam plants can reduce the tremendous amounts of water needed for condenser cooling by resorting to cooling towers and cooling ponds. By this means water can be recirculated through the condensers and the volume of water needed can be reduced to 4 or 5 percent of the amount used in a conventional plant. The percentage of consumptive use is greatly increased over that at conventional plants but the volume is relatively small. In addition to the initial cost of cooling towers, this method may involve some reduction in efficiency of power generation because the water may be warmer than that taken from a large reservoir or regulated stream. Increased power is needed by circulating pumps and fans. Cooling ponds are not as expensive to operate and maintain as towers but large areas of land must be acquired for the ponds. An important advantage of the use of cooling towers and ponds is the greater freedom from site limitations that it provides. Plants can be located closer to coal fields and load centers, thus reducing transportation and transmission costs. None of the TVA steam-electric plants in the Valley now use these means of cooling condenser water but a 2-unit, 450,000-kw plant has recently been completed in the upper Clinch River basin that uses cooling towers. The plant requires about 10 cubic feet per second of condenser water per unit as compared to 200 to 300 cubic feet per second at the large TVA plants.

Industrial Possibilities--Re-use of water is also an important means available to industry for stretching a water supply. No detailed information is available as to the extent of this practice in the Valley. However, the 1954 Census of Manufactures showed that 134 of 191 industries interviewed in the Valley counties recirculated or re-used water. The Census reported that these industries would use 50 percent more water if they did not recirculate or re-use. Re-use was greatest in the French Broad River basin where 13 of 16 establishments said they would average using twice as much water without recirculation. Only 10 percent of the total number of establishments in the Valley treated the water prior to recirculation. Other steps industry may use to reduce volume of water use include: checking all fixtures for waste and making frequent surveys for leaks; installing meters on all types of use; using automatic valves on controls; insulating hot and cooled water lines and placing thermostatic controls on cooling systems; using separate pipelines for various grades of water; reconditioning waste and wash waters; examining all processes for possible adjustment of water needs, and searching for substitutes for water in the manufacturing process.

Reducing Irrigation Use--There are possible ways of saving water in irrigation. Irrigation as presently practiced in the Valley is largely based on the individual farmer's experience and judgment. Few, if any, farmers measure how much rain has fallen on their crops or have soil moisture instruments to determine how much moisture is needed. It is doubtful if any make computations of soil moisture conditions based on evapotranspiration and rainfall data or have such data available to them.

Even an experienced farmer is likely to apply irrigation water inefficiently when he lacks technical information. He should, for example, have information on his soils and the rate at which they will take water. He needs to know which crops and soils respond best to irrigation, the amount of water required for various crops, and the periods when the application of this water will produce best results. He perhaps should have simple instruments to determine rainfall and soil moisture conditions. He needs to keep records of the cost of irrigation and the value of increased production to determine whether the water is being used economically. These and other problems are being studied on a limited basis by agricultural experiment stations throughout the humid east. Farmers could derive much benefit from organized programs of research on the economics of crop response to fertilizer use and related cultural practices, coupled with irrigation treatment and covering a range of soils and climatic conditions. The adoption of practices based on this type of research should substantially increase the efficiency of water use by irrigators.

Rural Use--The opportunities for reducing losses in the use of water in rural homes appear small. Rural uses are surprisingly large in the Valley, withdrawing nearly four times as much water in 1956 as irrigation and consuming about twice as much as irrigation. As more rural homes and farms are piped for water, loss or waste of water will increase as it does in unmetered city homes. It will be restricted somewhat, however, by cost of pumping and by limited supplies.

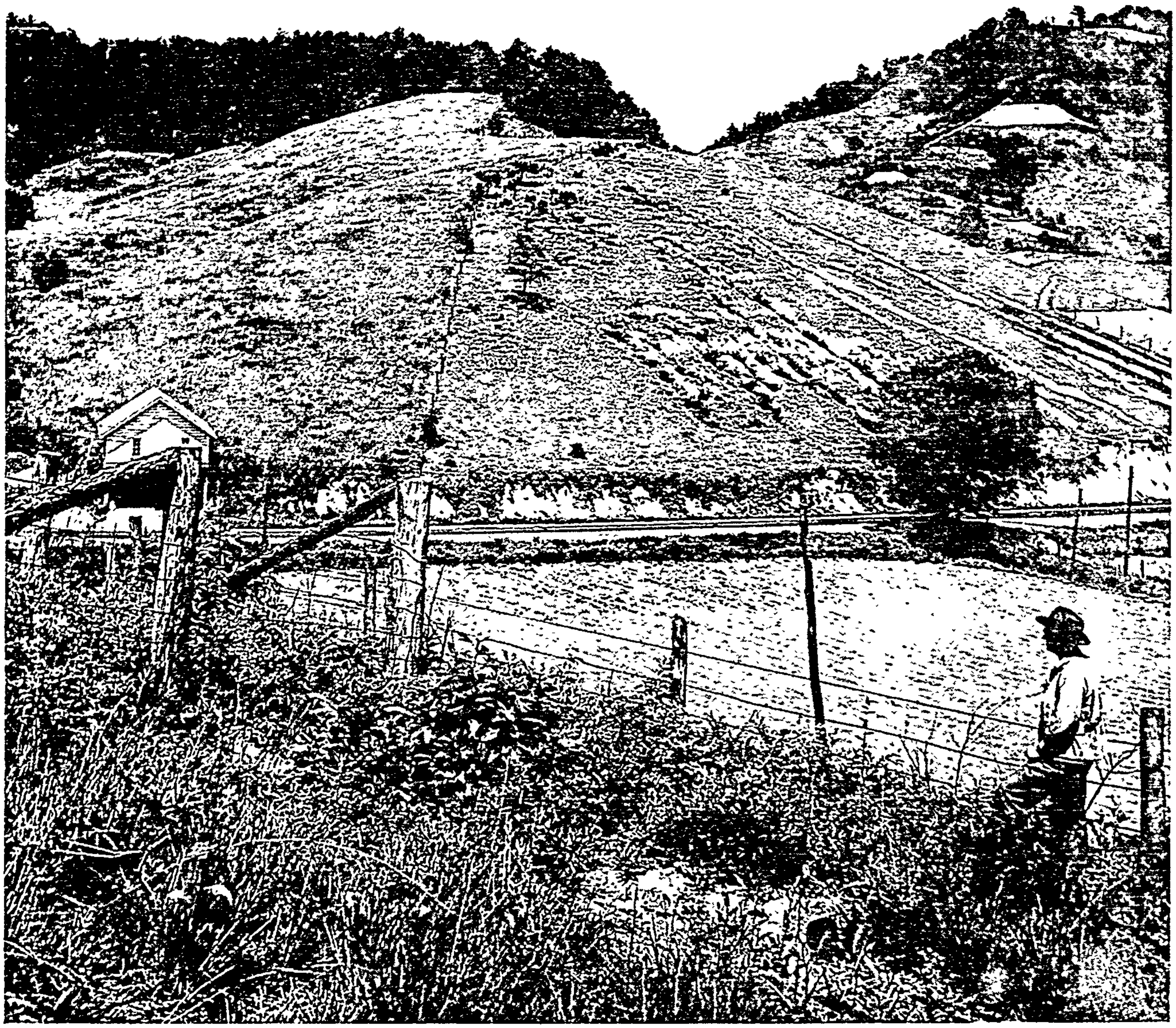
Control of Water on the Land

The management of a watershed, and particularly of its vegetation, has a considerable effect on the production of usable water from the watershed. The effects of agricultural and forestry management in controlling water on the land of the Basin have been investigated by studies on several small watersheds. The observations and measurements made during these studies provide data which indicate that important benefits have resulted over the Basin from the programs.

Sediment Reduction--Substantial reduction in the loss of soil has occurred from the index watersheds as a result of improved land use. One example is the 85,000-acre Chestuee Creek watershed in eastern Tennessee where work has been carried on over a 10-year period to improve watershed cover and land management. During this period, land in crops was reduced a net 6,353 acres; pasture land acreage was increased 6,395 acres; and land in forest was increased 946 acres. With these changes the annual suspended sediment load from the watershed decreased 48 percent in the 10 years.

An even more dramatic reduction in sediment removal has occurred on the Pine Tree Branch watershed, an 88-acre area in western Tennessee which in 1941 was characterized by numerous gullies and severe sheet erosion. In that year the land cover consisted of 23 percent understocked forest, 9 percent sparse pasture, 16 percent cultivated land, 50 percent abandoned and idle land, and 2 percent miscellaneous land, all in generally poor condition. A program of tree planting, contour furrowing, diversion ditching, and check dams was carried out from 1941 to 1945. By 1950 over 98 percent of the area was in forest, ranging from sparse (6 percent) to good (85 percent). A rapid reduction in erosion activity accompanied this land cover change, and by 1950 the annual sediment production was only one-tenth of the average rate in the pre-treatment years.

A similar change occurred in the White Hollow watershed, an area of 1715 acres tributary to Norris Reservoir. This area, all of which had been in cultivation at sometime in the previous 150 years, was purchased by TVA in 1934 as part of the reservoir land acquisition program. The land was severely



Erosion checked in TVA Test Demonstration

The two sides of this hillside in Madison County, North Carolina, were equally eroded. The picture illustrates the effectiveness of well-fertilized orchard grass and clover in holding the soil.

eroded, and gullies were numerous and active. During the past 24 years the watershed has been under forest management and protection. Tree plantings and natural revegetation have covered all of the cleared land and the area is now practically 100 percent forested. For the water year 1935-1936, the sediment load for the average storm was 7.3 tons. By 1951-1952 the load was only 0.5 ton, a reduction of 93 percent. The greatest reduction occurred in the early years. No significant reductions have occurred since 1952.

These samplings of the effect of watershed improvement in reducing sediment load are representative of what has happened over similar areas elsewhere in the Tennessee Valley. Observations of sediment deposition in the TVA reservoirs during the past 25 years indicate that these deposits are less than was originally computed on the basis of suspended load observations during the years 1935-1937. This is largely a result of the agricultural and forestry programs.

Storm Runoff Reduction--The amount of surface runoff from a watershed depends upon several factors, among the most important of which are the intensity and duration of rainfall and the slope of the land, neither of which is subject to control. For given rainfall and slope conditions, however, large variations in runoff occur due to differences in infiltration, percolation, and soil storage capacity, all of which can be modified by land management. Surface runoff will be least where all of these characteristics are high.

The same management practices that serve to reduce erosion are also effective in retarding the movement of storm water into the channels. Forests have a substantial regulatory effect on streamflow. Well managed forest stands, protected from fire, grazing, insects, and disease, increase the water storage capacity of the soil and create conditions that lead to maximum infiltration and percolation of water in the ground. Well managed grasslands have a similar effect in protecting the soil surface from raindrop impact, checking surface flow, and maintaining infiltration rates.

In the Pine Tree Branch research watershed, hydrologic observations show that the reforestation and erosion control program resulted in a marked reduction in peak discharges for both summer and winter floods. Peak rates of discharge from comparable moderate to large storms in the period before treatment averaged about 3 to 4 times those in the period after treatment. Surface runoff volumes from individual storms before treatment were 1-1/2 to 4 times those after treatment. These reductions in surface runoff volumes were essentially the same for both winter and summer storms, a condition which results largely from the year-around effect of a coniferous cover.

In the White Hollow watershed, the peak discharges in the summer season have been reduced, for comparable storms, to an amount only 5 to 27 percent of those initially observed. The reductions in peak discharges in winter are much smaller but are large enough to be detectable. The greater part of the summer peak discharge reduction occurred in the first two or three years of the investigation, indicating the rapidity with which peak flow reduction can be obtained by improving vegetal cover.

In western North Carolina a small watershed research project has been under way for several years to determine water-land relationships for some of the principal agricultural soils of the area under various vegetative covers. The work is planned to obtain information on the effects of single agricultural practices or types of cover on runoff, soil moisture, and ground-water levels. Since 1949 observations have been made of peak discharges from these small watersheds which range in size from 3.5 to 5.6 acres. A preliminary examination of the data shows the following relationship of peak discharges in cubic feet per second per acre from six different cover situations:

Cover	Average of 3 Highest Peak Flows cfs per acre
Corn	2.4
Transition	1.7
Wheat	1.4
Broomsedge	0.8
Overgrazed pasture	0.5
Improved pasture	0.4

Water Yield--The measures which have reduced soil erosion and storm runoff on research watersheds in the Valley have not resulted in any significant loss or gain in total water yield from the areas. In the Pine Tree Branch area, surface runoff volumes have decreased and ground-water discharges have increased. There is some indication of a slow, progressive, decrease in water yield. In the White Hollow area, no appreciable change has occurred in water yield.

To increase total water yield, a program aimed at reducing evapotranspiration losses is necessary. This might result from heavy cutting of forest stands, cutting stream bank vegetation, or replacing deep-rooted trees with shallow-rooted trees. In the Coweeta Hydrologic Laboratory in western North Carolina, a clear cut was made on a small mountain watershed with deep soils and a relatively high water storage capacity. In the first year runoff increased 15 inches. However, as sprouts and other growth reoccupied the ground, this increase fell off 4 inches in 3 years, 7 inches in 7 years, and 10 inches in 12 years. It was predicted that water yield would be the same as before the cutting after about 35 years. On shallower soils than those at Coweeta one would expect the effects of clear cutting to be considerably less.

In another Coweeta study, about 12 percent of a 22-acre watershed was cut back along stream channels and the bordering slopes. This resulted in an increase in streamflow of about 15 percent without increase in erosion. An important limitation in attempts to obtain increased water yield is the need to maintain adequate protection of the land surface against erosion and the need to maintain optimum growth on commercial forest lands which support a large share of the economy.

Increase in the Base Flow--The minimum flow of streams and springs during dry summers comes from ground-water storage and depends upon the extent to which previous rainfall has been stored deep within the soil beyond the reach of trees and other plants. This water is slowly released to springs and streams at a rate depending upon the character of the soil and rock through which it must pass before reaching the surface in the form of seeps or springs.

The amount of such water is dependent upon many factors, but especially upon the amount of rainfall in the region, the character of the cover and soil which influence infiltration and deep percolation, the amount of storage space in the soil, and the management applied to the surface of the soil. If the surface of the soil has a complete cover of plants, maximum infiltration will be obtained. If these plants are deep-rooted, leaving channels in the soil after the decay of roots, both percolation and maximum storage will be improved. Such soils usually have abundant soil fauna which also develop channels, improving percolation. Thus practices such as the growing of trees and deep-rooted crops can best provide improvement in internal soil drainage, leading to maximum storage of water and the enhancement of low flows.

In a study made in California by P. B. Rowe during a four-year period from 1933 to 1938, lysimeter tests showed that percolation water, which presumably would go to deep seepage, amounted to 112.21 inches for a litter covered soil, as against 46.19 inches for bare soil. Thus the litter covering caused almost three times as much water to get into the soil.

A study made by TVA on the Pine Tree Branch in Henderson County, Tennessee, showed that for the ten-year period after tree planting and treatment this 88-acre watershed increased its yield of ground water from 31 percent to 56 percent of the total runoff, and reduced surface runoff from 69 percent to 44 percent of the total. More significant, however, is what happened to the low flows during the summer months. During the period before treatment from 1941 to 1945, in the months of June, July, and August, only 6 percent of the rainfall appeared in the stream as ground water but after reforestation and treatment during the period 1946 to 1950, 24 percent of the rainfall during the same three months appeared in the stream as ground water. This was an increase of 400 percent in ground water production due to reforestation and other erosion control measures.

On another study of a 1700-acre watershed in White Hollow in Union County, Tennessee, there was little change in ground water flows fifteen years after treatment, as compared with the before treatment period. The soils here are more permeable than in the Pine Tree Branch area, consisting mainly of a cherty silt loam on the surface. It is probable that treatment measures such as those applied to these two watersheds will be more effective in maintaining or increasing low water flows on the tighter clay and impermeable soils than on soils where infiltration and pore space are already high.

These examples illustrate that the flow of water in springs and streams during periods of drought may be increased by those land management and land treatment measures which increase infiltration of rainfall into the soil, improve percolation, and increase storage capacity. Some of the measures which would bring about improvement would be elimination of grazing, elimination of fire, tree planting, introducing deep-rooted vegetation, and generally developing an effective year-round ground cover in fields and forests. Such practices would be particularly significant in maintaining water supplies for municipal watersheds, stock ponds, fish ponds, irrigation impoundments, and for maintaining stream flows for stock watering purposes during drought periods. While at present we have indications of the effectiveness of practices mentioned above, much more research is needed to develop the actual relationships and quantitative effects.

Effect on Tennessee Valley--No one has yet attempted to calculate the effects of the Valley-wide agricultural and forestry management programs on the complex hydrology of the larger stream basins. Probably enough streamflow and rainfall data are available to make the calculations possible, and the new computing machines may make them feasible. In the absence of these verifications we can only judge from the evidence of the small watershed investigations that the accumulative effect of these programs in reducing erosion, flood peak flows, and storm runoff on some of the poorer basins of the Valley must be significant and that there may also have been some benefit in the improvement of ground water supplies and the low flows of surface streams.

Impoundments and Diversions

Most of the sizeable streams of the Valley have average annual yields exceeding one cubic foot per second per square mile of drainage basin. Many yield up to 3 or 4 cubic feet per second per square mile. If this water were evenly distributed through the year it would satisfy most needs for water for many years to come.

Impoundment of surplus winter and spring flows for use in summer and fall is a means of approaching this uniform flow condition. Impoundments also permit the storage of small flows over relatively long periods to meet a peak demand of several times the average flow for a short period. In a number of potential shortage situations that appear imminent on the smaller streams, single purpose and multiple purpose impoundments seem to offer the only reasonable solution.

Duck and Elk River Impoundments--The situation on the Duck River at Columbia, Tennessee, where restriction of future industrial development threatens because of water supply limitations, is an example of the need for regulation of streamflow. Dry season flow of the Duck River at Columbia comes largely from the ground-water resources of the Highland Rim some distance upstream. The 30-day minimum average flow of record at Columbia is about 23 million gallons per day. Use and re-use of water by the industrial complex in the Columbia-Mt. Pleasant vicinity totals about 37 million gallons per day from the Duck River and tributary creeks. The continued development of consumptive uses such as irrigation above Columbia could aggravate an already serious water supply situation. A series of off-stream reservoirs or a single large upstream impoundment on the Duck River seem to be indicated as a solution.

Several satisfactory dam sites have been identified on the Duck and Elk Rivers where water could be impounded for streamflow regulation. One or more of these dams could provide reservoir storage space to retain a part of the heavy winter runoff and make it available to supplement the low flows during the dry season of each year.

A dam on the Duck or Elk Rivers could serve more than one purpose, possibly providing sufficient regulation for irrigation and water supply while at the same time contributing to flood control and power generation. The size of the structure and the method of operation would necessarily depend on the intended functions. Generally speaking, however, a large part of the reservoir volume would be available, if needed, during each period of drought.

Water for irrigation would be needed most during the months of June through September, with some minor water requirements during the months of May and October.

In the Duck River basin any of several sites could be developed effectively for irrigation and municipal water supply. However, one location above Shelbyville appears to offer the best possibilities for increasing the average dependable flow. Height of the dam would depend on minimum water requirements which would, in turn, determine the amount of storage needed to supplement the minimum natural flows.

Based on available records, the minimum average flow during the 4-month period of June through September has been about 128 cubic feet per second at Columbia. The following table gives approximations of the possible increased minimum flows, with some ideas of the cost of obtaining the increased water:

Reservoir Capacity (Acre-Feet)	Dependable Flow June-September With Use of Reservoir (CFS)	Cost Per Acre-Foot of Storage	Cost Per Dependable CFS
209,000	750	$ 58	$16,000
86,000	490	85	15,000
18,600	205	220	20,000

It can be seen that an impoundment of 18,600 acre-feet would increase the dependable June-through-September flow from 128 to 205 cubic feet per second at a cost of about $220 per acre-foot of storage space, or about $20,000 per dependable cubic foot per second. Larger reservoirs could be built to increase the summer flow even more with appreciably lower unit costs, but requirements may never justify such projects. Impoundments at sites below Shelbyville could provide equal or greater storage at similar unit costs--about

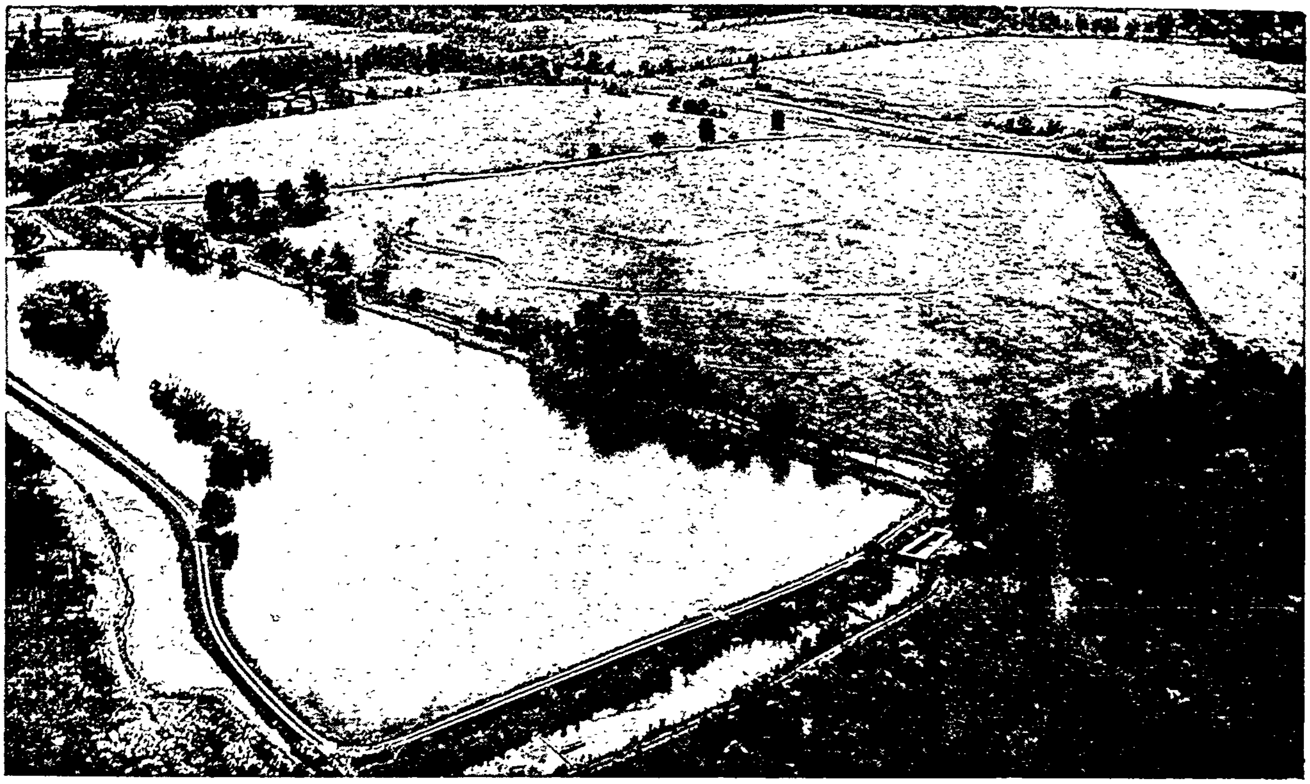
$200 to $250 per acre-foot and $20,000 or less per dependable cubic foot per second at Columbia for the smaller dams.

In the Elk River basin, attractive sites have been identified above Fayetteville, where impoundments could provide the necessary storage space to supplement summer flows. The minimum June-through-September average flow of 200 cubic feet per second at Fayetteville could be increased to about 285 cubic feet per second with a reservoir of 20,000 acre-feet at a cost of about $200 to $225 per acre-foot of reservoir storage, or about $15,000 per dependable cubic foot per second. A larger impoundment, if feasible, would be cheaper per unit. For example, a reservoir of 50,000 acre-feet would increase the minimum June-through-September flow to about 410 cubic feet per second at a cost of about $120 to $130 per acre-foot of storage, or about $15,000 per dependable cubic foot per second.

Effect of Multiple Use--Use of such reservoirs for other than water supply would alter the dependable flows and the costs mentioned above. For example, flood control might require that the reservoir be held at low level until it is too late to assure filling the reservoir completely before June. Operation to meet power requirements would mean use of water throughout the year rather than only during the summer months, and might even prevent filling to desired levels. During the summer, power discharges might be needed only during a few hours of each day, creating a problem for users depending on a constant flow in the river channel.

Multiple-purpose use could probably be satisfactorily planned, but certain conflicts are inevitable as compared with single-purpose operation. However, there is no reason to doubt that adjustments could be made to ensure adequate multiple-purpose operation.

Farm Ponds--Farm ponds are much used throughout the Valley for livestock water, recreation, and to some extent for irrigation. The livestock water use is the principal one and has been in the past the chief reason for building the ponds. There has been an increasing trend in recent years toward larger multiple-purpose ponds that can be used also for recreation. About one-half of the ponds now being built are planned to include these uses. Most farm ponds in the Valley are off-channel impoundments fed by direct surface runoff.



Air view of large pond in Catoosa County, Georgia.

Planned principally for recreation, the water is used also for irrigation and stock watering.

Multiple-purpose farm pond.

In 1957, there was an estimated 54,300 farm ponds in the Valley. These had a combined area of 37,000 acres and a total volume of 82,000 acre-feet. About 6,000 were in the Duck River basin and about 30,000 were in the portion of the Valley west of Guntersville Dam.

Abatement of Pollution

A previous section of this report has described the severe pollution of several large streams of the Valley which restricts their usefulness as water sources. Among these were the North Fork Holston River, the Pigeon River, the French Broad River, and the lower Tuckasegee River. In the streams cited, much of the damaging pollution originates in one state (Virginia or North Carolina) and is carried by the stream into another state (Tennessee). Some smaller streams are also heavily polluted by industry.

State Responsibility--Present law and policy makes the solution of these pollution problems primarily the responsibility of the states concerned. Section I of the Water Pollution Control Act Amendments of 1956[1] states that, "In connection with the exercise of jurisdiction over the waterways of the Nation, and in consequence of the benefits resulting to the public health and welfare by the prevention and control of water pollution, it is hereby declared to be the policy of Congress to recognize, preserve, and protect the primary responsibilities and rights of the states in preventing and controlling water pollution."

State Laws--All seven of the Valley states have comprehensive stream pollution control laws. The Tennessee law was passed in 1945 and amended in 1951. The Virginia and Mississippi laws were passed in 1946, the Alabama law in 1947, the Kentucky law in 1950, and the North Carolina law in 1951. Georgia, which for many years had an extensive program of pollution control administered under the common law, passed a water quality control act in 1957.

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1. Public Law 660, 84th Congress, approved July 9, 1956.

Accomplishments--Through the use of these pollution control laws the Valley states have already accomplished much in the reduction of municipal pollution and have made headway in reducing industrial pollution. Continued progress in abatement will mean greater availability of surface waters for all water users in the Valley.

Interstate Compact for Pollution Control--An interstate compact for control of stream pollution in the Tennessee Valley has very recently been made a legal entity. Originally proposed by the state of Tennessee, the compact was approved by the Tennessee Legislature in 1955. The Mississippi Legislature ratified it, and that state joined the compact in 1956. Kentucky ratified the compact in August 1958. On August 23, 1958, the compact became law. This law establishes a commission composed of residents of each Valley state with authority to set up standards of water quality and to enforce antipollution orders.

Federal Control--As stated previously, the Water Pollution Control Act Amendments of 1956 recognize the primary responsibilities of the States in controlling pollution. However, if requested by either State involved with another concerning pollution passing from one to the other, the Federal Government is empowered to investigate the facts, hold hearings, and, if necessary, bring suit on behalf of the United States to secure abatement.

Weather Modification

The present outlook for cloud seeding in the Tennessee Valley is that such operations are not economically feasible in this area.

Summing up the present status of cloud seeding generally, the World Meteorological Organization, a recognized international meterological body, concluded as follows in a report on artificial inducement of precipitation:

1. Operations which have so far been carried out have produced results that could be termed, at best, inconclusive; neither the complete failure of the methods employed nor the certainty of getting substantial increases of rainfall, have been demonstrated.

2. The most favorable meteorological conditions for the artificial inducement of precipitation are to be sought in regions and during seasons where natural precipitation is most likely.

3. Present day techniques, either "cold" or "warm" cloud seeding, have very little value, if any, in augmenting the precipitation in areas of very low rainfall or during dry periods in regions of normally medium rainfall.

These tentative conclusions by WMO are not expressions of a negative attitude but rather indicate that further effort is necessary before there can be any assurance of positive results from cloud seeding.

OPPORTUNITIES FOR STATE ACTION IN WATER RESOURCE DEVELOPMENT

The severe drought years 1951 to 1955, occurring in a period of rapid economic progress and expanding use of water, stimulated investigative studies of the whole water resource situation in most of the eastern states. In the Valley area, these state studies have shown the need for carefully planned, long-range water resource and other related programs to protect the water supplies and provide for their best development in the future. There is a growing appreciation that the abundant supplies of water of suitable quality available in the region are a dynamic factor in stimulating and supporting regional economic growth.

Conservation and development of the water resources of the Tennessee Valley region are a joint responsibility of state and Federal government and private enterprise. It is essential that the state and Federal programs and activities continue to supplement each other so as to add strength to their combined efforts. The people of the region, acting as individuals and through public agencies, are benefitted by water resource programs which are planned to serve their needs and to encourage social and economic development. Potential conflicts between immediate and long-range objectives and between specific and general benefits should not be allowed to obscure the advantages of well-designed programs.

The discussion below suggests some directions that planning and development programs might take to protect both the water resources and those who use them.

Maintaining Up-to-Date Water Resource Information

One of the important functions of a state water resource program should be the collection, interpretation, and publication of detailed and up-to-date information on the state's water resources and water uses. The state should be in a position to give information, advice, and direction to local governments and private enterprises and to help them care for and use the resources. Basic water resource and use data are essential for this purpose as well as for the formulation of adequate long-range plans for resource development.

The Federal agencies, such as the U. S. Weather Bureau, Geological Survey, TVA, Corps of Engineers, and the Department of Agriculture, can be of much help in supplying and interpreting basic data. A number of state agencies collect information on municipal and industrial use, irrigation, stream pollution, and other phases of water use. This multiple collection of data needs to be coordinated for state use on a continuing basis, probably by a single agency which would be responsible for assembling all water resource data and for the analysis and dissemination of these data. This agency might be empowered to arrange for expansion of the existing network of stream gaging stations and water quality sampling stations so that basic data on water resources will be available for present and future needs of water users.

Water Supply Data for Industry--The state agencies concerned with water resources could compile and interpret information for ground-water sources and for all sizeable streams at locations which might be attractive to industry. Such information for streams would include data on amount, frequency, and duration of low flows, flow duration curves, data on past flood heights, and predictions of possible future floods. Since many industries have rather stringent water quality requirements, available information on the mineral, physical, bacteriological, and sanitary-chemical qualities of ground water and of water in the streams should be assembled and programs developed with the Federal agencies for additional sampling.

Municipal Water Supplies--The state water resource agencies could render an important service by assisting in the investigation of the water supply situation in small municipalities to appraise the probability of future shortages. The state agency might either help the municipalities directly in protecting their supply or recommend the services of a consulting engineer, competent in the field of municipal water supply.

Shortages of municipal water can produce real hardship and serious disease, and adequate advance planning is essential for protection of the water users. Also if a municipality is to attract an industry, it must be in a position to assure an adequate water supply to the industry at all times. The impact of new industry on a town's water supply system is exemplified by the recent experience of Lawrenceburg, Tennessee. The town built a new filter plant with a capacity of two million gallons per day, enough to supply its normal needs for water until 1980. Before the new filter plant was completed a new industry requested a supply of one million gallons per day. By the time the filter plant went into operation another new industry with a requirement of one million gallons per day became a certainty. Thus a 24-year design period on a water supply was expended in two years.

Other Basic Data Needs--There is a significant deficiency in the knowledge of average and low flows on the thousands of small streams that are the source of supply for many irrigators, cities, and industries. The U. S. Geological Survey has a program under way that will help correct this deficiency. The state agencies would find it advisable to support this program. Intelligent administration of a permit system or other legislation controlling water use would be difficult without such data.

Data on flood heights and flood discharges are of value to state and local agencies and private enterprise in selecting industrial sites and subdivision locations, controlling land use in flood plains, and designing highways, bridges, sewage plants, water treatment plants and other structures close to streams. The TVA, Corps of Engineers, and U. S. Geological Survey have been collecting flood data for many years. The state agencies might establish cooperative programs with these Federal agencies to expand knowledge of past floods and to determine probable magnitudes of future floods.

There is need for additional study of drought occurrences and drought frequencies in the Valley region. Basic data for these studies are available in the files of the U. S. Weather Bureau and TVA. Some analysis has been carried out by TVA and the Department of Agriculture. Further research by the state agencies is needed, particularly in connection with the use of water for irrigation.

Planning for Industrial Development

The Tennessee Valley states offer many advantages that encourage new industry to investigate for locations in the region. The attractiveness of the area for industrial development is enhanced by adequate water resources, including water transportation, ample water supplies, water based recreation, low cost power, and flood-free plant sites on the larger streams. Advance planning by the states would be desirable to insure that these attractions will remain available to new industry.

Waterfront Industrial Sites--Sites suitable for industry on or near the shores of reservoirs and large streams are far from plentiful. Private recreational and residential developments, for example, are rapidly pre-empting sites that are particularly adaptable to large industry. This has been true along the Tennessee River where there is available good barge transportation, large supplies of water, and a substantial degree of flood protection. In the 25 years since 1933, more than 100 new industrial plants or navigation terminals have been established along the Tennessee River and its navigable tributaries, representing a capital investment of nearly three-quarters of a billion dollars. This trend may be expected to continue only if local agencies provide adequately for the development and best use of the remaining waterfront lands.

Along the larger streams of the Valley states, such as the Mississippi, Ohio, Cumberland, and Tennessee Rivers, steps might be taken to reserve sites for industries requiring large quantities of unpolluted water and ready access to barge transportation. For site planning and zoning purposes, the industries might be classified in three categories: (1) those that need large amounts of process or cooling water but do not need barge terminals; (2) those that need waterfront terminals but only moderate amounts of water, and (3) those that need both terminals and large water supplies. Industries in the first group could establish on sites one or two miles back from the river as long as they maintained access to the water for pipelines and for transport of materials to and from the river. The other two groups would require waterfront sites. Consideration of these locations would increase the number of available sites for industry especially in reaches where the waterfront land is not suitable. State agencies might find it desirable to have data on these sites that are away from the water as well as on the prime waterfront locations.

Planning for Urban Development

The continued expansion of the urban areas and the increase in manufacturing, trade, and service industries gives added importance to state and local agency planning for waste disposal and local flood control.

Control of Stream Pollution--Each of the state stream pollution control agencies has, in recent years, been doing a commendable job of interpreting and enforcing the state stream pollution control laws. This is particularly true with regard to the control and abatement of pollution resulting from municipal sewage. Progress in the reduction of industrial waste discharged into streams has not been as rapid as that in municipalities, largely because these industrial wastes seldom pose a threat to public health. In addition, each state is interested in attracting new industry and in not burdening existing industry with costs of waste treatment. As the states become more industrialized, however, the need to protect existing water supplies, both municipal and industrial, will swing state policy toward stricter control of industrial wastes.

If the states encourage their pollution control agencies to maintain the rate of reduction in municipal pollution that they have been so instrumental in producing during the last few years, there will soon be few pollution problems in the Valley due to municipal sewage. New or modernizing industries investigating for sites within city service areas will be especially interested in knowing whether a municipal disposal system can handle their wastes or if pre-treatment or separate treatment will be needed. Up-to-date information could be compiled by the state agencies to answer these questions and planning advice given to the municipalities to insure that designs allow for added capacity to be installed.

Some rather serious problems of interstate pollution exist among the Valley states. These can best be solved through full participation in pollution control compacts such as the Tennessee River Basin Water Pollution Control Compact which became Public Law 734 of the 85th Congress on August 23, 1958. Only three of the Valley states had joined the compact by the end of 1958. The other four would do well to join to provide a workable means of solving the Valley problems.

<u>Flood Damage Abatement by Land Use Controls</u>--On such streams as the Tennessee and Cumberland Rivers and their larger tributaries, systems of flood control reservoirs have either eliminated the threat of floods or have greatly reduced the height and frequency of overflows. However, flood problems are still unsolved in many urban and rural localities along the tributaries where no controls exist. In a great number of these situations, local protective works or upstream control by reservoirs cannot be justified. In such instances, relief from flood loss may be feasible only through a program of land use controls, including flood plain zoning, subdivision regulations, land acquisition for parks and other public uses, urban renewal projects, and occupancy standards for structures that must remain in the flood hazard areas. The solution to these problems is within the powers of the state and local governmental units. These powers must be used if future flood damages are to be reduced or prevented. State and local agencies need, therefore, to actively support and carry out programs for land use controls in flood plain areas.

In addition, a cooperative state and Federal program is necessary in each state for the collection, analysis, and publication of flood data which will be needed by the cities and communities in their flood abatement planning. During the past five years, TVA has carried on such studies at the request of cities within the Valley boundaries. Approximately 40 studies had been completed by the end of 1958.

This subject was discussed at the Conference on Flood Plain Regulation and Flood Insurance, held at Chicago on December 1 and 2, 1958, and sponsored jointly by the Council of State Governments, the American Society of Planning Officials, the American Institute of Planners, the American Society of Civil Engineers, and the University of Chicago. The conclusions of the Conference were distributed by the Council of State Governments on December 22, 1958. These conclusions urged more state responsibility and activity in this field and urged close cooperation between state and Federal agencies. The General Assembly of the States, at its 14th Biennial Meeting in Chicago on December 5, 1958, passed a resolution which "commends to the attention of the states and the Federal Government the conclusions reached by the Conference and urges their implementation by necessary administrative and legislative action."

Protection of Water-Based Recreation

The states of the Tennessee Valley area have made commendable progress in the development of park and recreation programs. These programs deserve increased state attention as public services, as conservation of economic resources, and as a means of attracting industrial development. Population growth, higher incomes, and better highways insure a rising demand for park and recreation areas. The lakes and mountains of the Valley area, coupled with a favorable geographic situation, give this area special advantages for the development of the travel and vacation business.

The states and local governments should be alert to acquire suitable and available shoreline areas for future development to provide public access to lakes and other water resources. Lack of foresight now may result in permanent loss. Scenic and recreational areas marred by other uses are difficult and expensive to repossess and restore. Advanced planning and a moderate capital investment now may pay large dividends in economic activity and human satisfaction.

The water resource developments of the past 25 years have greatly benefitted sport and commercial fishing and the hunting of migratory waterfowl in the Valley states. Joint investigation by the states and Federal agencies may reveal possibilities for further improvement in these important by-products of the large reservoirs built by the TVA and the Corps of Engineers.

Conservation on Watersheds

Land use is inseparably related to the management of water resources. The function of a watershed is to receive and distribute rainfall with a minimum of erosion. The soil of the watershed must have certain characteristics of stability, absorption, and retention of water if it is to perform this function satisfactorily. These characteristics are affected materially by the plant cover which in the Valley states is about evenly divided between forest and open land. Since a very high percentage of this land is privately owned, state and Federal agencies need cooperative educational and demonstrational programs to encourage land management which will return a profit to the owner and at the same time provide more and better water supplies for the public good.

The small watershed demonstration program established by TVA is an example of state-Federal cooperation in such an educational program. The ultimate goal of this program is the state-wide and Valley-wide improvement of the hundreds of small watersheds where landowners are experiencing difficulties in securing the efficient utilization of their land and water resources.

Small-Multiple-purpose Reservoirs

The state governments in the Tennessee Valley area may want to consider the development of storage reservoirs to meet future needs and to stimulate economic growth. A considerable gap now exists between the major multiple-purpose stream control dams constructed and operated by the Federal agencies and the local farm ponds and scattered small watershed programs. The filling of this gap may be dependent upon the states and private agencies. The states may well give consideration to building small multiple-use reservoirs for flood control, industrial and municipal water supplies, recreation, irrigation, and power. State initiative in this field might result in a joint Federal-state planning and financing of a highly useful program. Such a program, combined with land-use improvements, would represent state action in the water resources field to complement development of industry and trade.

Economic Relationships Among Water Uses

Even in a water-abundant region such as the Tennessee Valley there are areas where water will be scarce relative to the demand for it. In these areas it will be necessary to make decisions between alternative uses and users and between storing and transporting water. This is primarily an economic problem and there is need for specialized research to develop the complicated economic relationships among the water uses.

This type of research ought to consider regional, state, and local water resources, projected water needs, and the values of the various uses of water. There is need for the development of analytical techniques that would permit the estimation of values of alternatives to the present uses of water. It is recognized that there are secondary and tertiary economic and social benefits of specific and related water uses, and that these benefits vary with varying patterns of water use. The development of the necessary data and the analyses will permit the making of sounder policy decisions for programs designed to secure the optimum level of water use in the public interest. This is a large and difficult task, but it can be successful if all state, local, and Federal agencies interested in regional resource development coordinate their efforts in conducting such studies.

CHAPTER 6

POSSIBLE NEED FOR NEW WATER RIGHTS LAWS

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INTRODUCTION

One of the most basic questions presently facing the states in the water resources field is whether present and potential water use requirements and conflicts call for changes in their water rights laws, and in their organizations for administering such laws and dealing with water problems generally. The importance of this problem has received increasing recognition in the Tennessee Valley states, as in the Eastern states generally, during the last few years. Comprehensive official studies of water problems and possible modifications of existing water rights laws have been completed or are now in progress in all of the Tennessee Valley states except Alabama. In Mississippi, the study process has been followed by adoption of a statute which, as respects surface waters, substitutes the western prior appropriation doctrine for the common law riparian rights rule.[1] Virginia, after giving extended consideration to the possible adoption of prior appropriation, has decided instead to retain the riparian rights rule while enacting legislation permitting riparian owners to capture and store flood waters under specified conditions.[2] North Carolina, after similarly considering and rejecting prior appropriation, has enacted a statute providing for allocation of water during periods of emergency.[3] In Georgia, Kentucky, North Carolina, and Tennessee, studies are still in progress.[4]

This widespread current interest in water laws and problems reflects such previously noted factors as several years of widespread drought between 1952 and 1956 and the growing public awareness of the extent to which use of water is increasing. Concern with the subject in the Tennessee Valley states is paralleled by similar concern during recent years throughout the humid eastern portion of the United States. The arid West has of course been vitally and continuously interested in the problem ever since that region's original settlement.

Value of Legal Rules

The ultimate test of any legal rule or system is whether and to what extent it will contribute to the social and economic needs of the area in which it is applicable. The basic need appears to be for a system of water rights laws which will facilitate a growing, balanced economy with a maximum of fairness and equity to individual interests which may be affected. Legal rules should provide, so far as possible, for a sufficient degree of certainty to render desirable investments feasible, and at the same time provide for reasonable flexibility and adaptability to desirable changes.

Legal rules cannot increase the supply of water potentially available. They can, however, determine who shall obtain water, and in what amounts, during periods of shortage. They can also help assure that the greatest potential supply of water will in fact be available, and can thereby minimize shortages which may occur or even, in some cases, prevent the occurrence of such shortages. Thus, rules regulating the point of return and degree of treatment of water used by municipalities and industries can make more of this water available to other water users located downstream. Even in the case of a highly consumptive use such as irrigation, legal rules can help minimize or prevent resulting diminution in water supply. For example, where necessary irrigators might be required to construct and use facilities to store water during the winter months as a condition to their use of water for irrigation purposes during dry periods in the summer and early fall.

Legal rules determining what groups of competing water users shall receive water and in what quantities during times of shortage, and establishing requirements which must be observed in using water, can have a considerable effect on the economy of the state or other area in which they apply. It is important, therefore, that each state follow legal rules which will promote conservation and the most desirable use of water in the public interest, in addition to providing as equitable results as possible from the standpoints of different competing users.

CLASSIFICATION OF WATERS AND GENERAL RULES CONCERNING THEIR USE

For purposes of considering private rights and obligations with respect to use, waters may be classified into four basic types:

1. Surface waters in well-defined streams.* These waters are subject to two basic systems of water rights law, the doctrine of riparian rights, followed generally in the Eastern section of the country, and the doctrine of prior appropriation, followed generally in the West. These two systems are summarized below.

2. Diffused surface waters. These are the waters which fall as rain and snow and spread over the ground before sinking into it or concentrating in water courses. There is a large body of law concerning damage from such diffused surface waters. There is very little law with respect to private rights of capture and use. Where the question has arisen, the courts have generally held that an owner of land has an absolute right to detain and use such water for his own purposes.[5] The courts seem to have given relatively little consideration, however, to how such an absolute right of capture can be reconciled with the rights of riparian landowners or appropriators on the stream into which such water would flow if it were not detained. In a few states, the question is governed by statute.[6]

3. Underground waters in well-defined streams. Rights in these waters are usually determined according to the same general rules which are applicable in the particular state in the case of well-defined surface streams.[7] Mississippi is an exception, since its new prior appropriation statute applies only to surface waters. Existence of a well-defined underground stream may be difficult to prove, and underground waters are presumed to be percolating in the absence of clear proof to the contrary.[8]

4. Underground percolating waters. Here there is considerable divergence among applicable legal rules. Georgia and Mississippi among the Valley states apparently still follow the English common law rule, which permits

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*Non-flowing surface waters such as lakes are not included as a separate category, since the legal problems and generally applicable legal rules concerning them are basically similar to those applicable in the case of surface streams.

an owner of land to withdraw percolating waters as he sees fit without regard to the effect of such withdrawal on other parties.[9] Alabama, North Carolina, and Tennessee follow the alternative doctrine, known as the American, reasonable use, or correlative rights rule, under which use of percolating underground waters is governed by the test of reasonableness similar to that applicable under the riparian rights rule as generally applied in the case of surface streams.[10] The legal situation with respect to underground percolating waters in Kentucky and Virginia is not clear.[11]

RIPARIAN AND PRIOR APPROPRIATION SYSTEMS

Riparian Rights

The riparian rights doctrine originally emphasized the right of all owners of land bordered or crossed by a stream to have its waters flow to them in their natural and normal course, undiminished either in quality or in quantity. Later development of the doctrine has emphasized the right of each riparian owner to make such use of the waters of the stream as is reasonable under all the circumstances existing at the time. A common statement of the modern rule, enunciated in a Massachusetts case and subsequently quoted approvingly on numerous occasions by other courts, is as follows:

> Each proprietor is entitled to such use of the stream, so far as it is reasonable, conformable to the usages and wants of the community, and having regard to the progress of improvement in hydraulic works, and not inconsistent with a like reasonable use by the other proprietors of land on the same stream above and below.[12]

A Tennessee decision similarly states the rule in that state to be:

> . . . that each riparian owner has an equal right to have the stream flow through his land in its natural channel, without material diminution in quantity or alteration in quality but with this limitation or qualification, however, that each proprietor is entitled to the reasonable use of the water for domestic, agricultural or manufacturing purposes.[13]

Reasonable Use--In determining what is a reasonable use, the courts give consideration to all of the facts bearing on the particular case. As stated by the North Carolina Supreme Court:

> What constitutes a reasonable use is a question of fact having regard to the subject-matter and the use; the occasion and manner of its application; its object and extent and necessity; the nature and size of the stream; the kind of business to which it is subservient; the importance and necessity of the use claimed by one party and the extent of the injury caused by it to the other.[14]

Limitations Resulting From Rule--The riparian rights rule thus recognizes that all owners of land along a stream have correlative rights to its use which each must exercise with due regard for the rights of all the others. Under the rule as generally applied, the right to use water may be exercised only by riparian owners and on riparian land.[15] Private owners of land not bordering on a stream can ordinarily obtain a right to use its waters only by prescription--that is, by originally wrongful use continued for a period specified by statute, often 20 years.[16] This is of importance not only to individual non-riparian landowners but to municipalities. In most states, withdrawal of water for municipal water supply does not represent an accepted riparian use even where the municipality is a riparian owner; such withdrawal for the benefit of a great number of persons is regarded as an extraordinary use which is not properly an incident of riparian status and which will inevitably involve use of most of the water on nonriparian land.[17] Municipalities can, of course, acquire rights to water through prescription or eminent domain. In a few states, apparently including Tennessee, the courts adhere to a minority view that municipal use is a proper riparian use.[18]

Prior Appropriation

The doctrine of prior appropriation is based on the principle, not of correlative rights, but of first come, first served. Although there are many variations among the laws of the Western states which follow this doctrine, they provide generally that water users, whether or not owners of riparian land, may establish rights to appropriate given amounts of water from a stream. Such a right, once established, is permanent (assuming continued exercise of the right by actual use of water for a beneficial purpose). Relative priority among rights is determined by the time when they were respectively established. Such priority is absolute, each appropriator being entitled to receive his full quantity of water before any appropriator junior to him is entitled to any water at all. The value of an appropriative right thus depends in large part on its place in the priority schedule.

Preference Among Uses--Where applications for rights to use water for different purposes are pending at the same time, preference among them is ordinarily determined in accordance with a ranking provided by the statutes of the particular state. Domestic and municipal uses are ordinarily preferred to irrigation, and irrigation to industrial use. These preferences are not universally applied. For example, Texas prefers industrial to agricultural use, while Washington determines the relative importance of competing uses according to the facts of each case.[19] Once an appropriative right has become established, it cannot thereafter be displaced in favor of a higher ranking use except by some form of eminent domain proceeding accompanied by payment of appropriate compensation.[20]

The California Doctrine--Some Western states follow (with numerous variations) the so-called California doctrine, under which both riparian and appropriative rights are recognized. In California, the riparian right is the dominant right to the extent that a riparian owner is making a beneficial use of water or can do so in the future. Water which is permanently surplus to riparian needs is subject to appropriation on a permanent basis. Water which riparian owners are not presently using, but which they can beneficially use in the future, is also subject to appropriation; but here the courts will protect the riparian right by providing that it shall displace the appropriative right when the riparian owner is in a position to make beneficial use of the water.[21]

ADVANTAGES AND DISADVANTAGES OF RIPARIAN RIGHTS AND PRIOR APPROPRIATION

In terms of encouraging conservation and optimum use of water, the riparian rights rule and the prior appropriation rule both have their advantages and their drawbacks.

The Riparian Rights Rule

From the standpoint of an individual riparian owner, a major advantage of the riparian doctrine is that in times of shortage he will be entitled, having a correlative right in the water, to share in whatever quantity is available. From the standpoint of the public, the major advantage of the rule is its flexibility. Since its application is based on the test of reasonableness, the courts in applying it can prefer uses which are socially desirable, accord due recognition to new uses as their public importance increases, and take appropriate action with respect to originally reasonable uses which may become unreasonable.

A major disadvantage of the system is the lack of certainty associated with it. Whether use of a particular quantity of water for a particular purpose is reasonable may not be definitely determinable without litigation. Until there is such a determination, the investment which the use requires may be difficult to justify. This is particularly important in the case of a highly consumptive use such as irrigation which is likely to lead to conflicts with other users, including other irrigators, whenever the supply of water is insufficient to meet all needs. Further, since riparian rights are not lost through non-use, riparian owners who make present use of water may have to limit such use when other riparian owners who have not previously exercised their rights decide to do so. Another disadvantage of the riparian system is that under it nonriparian owners may find it difficult or impossible to obtain water in cases where their use of water would be economically and socially desirable.

Prior Appropriation

Prior appropriation voids much of the uncertainty inherent in the riparian rights rule. Each appropriator is entitled to a definite quantity of water, and his established place on the priority schedule provides at least some indication of the extent to which he can count on such quantity being actually available to him during a period of water shortage. Prior appropriation also has the advantage of enabling nonriparian as well as riparian owners to obtain rights to use water.

The great disadvantage of the prior appropriation system is its lack of flexibility and the "freeze" which it tends to place on future changes in water use to meet changing economic and social conditions. Once the water of a stream has been fully appropriated, adjustments to meet new and superior needs can be made, if at all, only with difficulty. That such a freeze is of far more than academic importance is indicated by the following quotation from a study included in the 1952 report of the President's Materials Policy Commission (generally known as the Paley Commission):

> Except for the Pacific Northwest, most of the economically available water of the Western States is allocated for irrigation and is not now available for large industrial requirements without costly acquisition of farm rights and properties. . . . The West has gotten only a small percentage of existing industries, and may get an even smaller proportion of future expansion unless large quantities of cheap water can be made available for manufacturing and other industrial uses. There is probably only one method by which this can be accomplished--curtailing a part of existing irrigation or plans for new irrigation when industrial needs develop. . . . the West must soon decide whether its future must be sacrificed by its antiquated priorities system in water use.[23]

The "freezing" tendency of prior appropriation applies even between appropriators desiring to use water for the same general purpose. Under prior appropriation, a junior appropriator desiring to irrigate inherently more fertile land for high-value horticultural crops may be forced to defer in times of shortage to a senior appropriator desiring to irrigate less desirable land for pasture. Again, a junior appropriator located in the upper reaches of a watershed may have to watch a stream flow past his property to satisfy the needs of a lower senior appropriator even though a considerable amount of water is lost through evaporation in the process. In such circumstances, "beneficial use," the touchstone concept of Western water law, can easily become wasteful use.[24]

THE PERMIT APPROACH AS AN ALTERNATIVE SOLUTION

Growing awareness that the riparian rights and the prior appropriation systems both leave a good deal to be desired has led to a search for alternative solutions. A completely satisfactory solution is unlikely. Any attempt to provide certainty and flexibility, equity among irrigators, equity between irrigators and competing users such as municipalities and industries, and reconciliation of the interests of all users of water with the public interest, will necessitate compromises. As one of the best known authorities in the field has stated, "claims of perfection promise too much as well for one system of water law as for another," and choice of a particular doctrine or controlling legal principle "need not signify an excellence in itself, but only that in this naturally difficult and elusive subject the evils of this test are less than the evils of its alternative."

At the present time, there is growing interest in a type of system providing for permits but not for appropriative rights. Several states have adopted laws providing for the issuance by a state agency of permits covering particular types of water uses. A more general kind of permit system is in operation in one state, Iowa; and a somewhat similar type of permit system is embodied in a suggested model water use act recently prepared by the Legislative Research Center, University of Michigan Law School, and endorsed by the Council of State Governments.

Basically, permit systems preserve existing uses undertaken under the riparian rights rule; require that new users (subject to certain exceptions, including all types of domestic use) obtain permits from a State agency; and provide that such permits shall not be granted on a permanent basis, as in the case of appropriative rights, but rather for a specified period of years, with provision for extension at the end of the original period if then existing conditions warrant. The permit system thus seeks to provide sufficient certainty for the individual user to facilitate his investment in water using equipment. At the same time, it retains an element of flexibility by making possible a shift to a more desirable use at the end of the permit period if any such use develops. It may also provide for forced transfer of a permit during the permit period on payment of appropriate compensation to the original permittee.

The Iowa System[25]

The present Iowa system, which dates from 1957, is the outgrowth of a long history of administrative interest in water problems, studies, and various legislative enactments extending back to the 1930's. The 1957 law provided for a state natural resources council charged with the general duty of establishing and administering "a comprehensive state-wide program of flood control; and a comprehensive state-wide program for the conservation, development and use of the water resources of the state." The Iowa law is discussed in some detail below as an example of a recent development in water resource legislation based on the permit approach.

Administration--The Iowa council is composed of nine members selected "from the state at large solely with regard to their qualifications and fitness to discharge the duties of office without regard to their political affiliation." Members are appointed by the governor, subject to confirmation by a two-thirds vote of the senate, for staggered terms of six years each. Council members serve on a part-time basis, and (unless they are public employees) receive twenty-five dollars per day each for their services, plus expenses. The council has a staff of full-time employees, the most important being a director, who serves as the council's executive officer; a water commissioner, who acts in a quasi-judicial capacity as a trier of fact questions arising in connection with permit applications; and deputy commissioners, who may act in the place of the commissioner.

Requirements and Exceptions--Subject to certain exceptions, permits in Iowa must be secured from the council as a basis for the diversion, storage or withdrawal of either surface or underground water. The principal exceptions are uses within municipalities existing on the date of the act, domestic and farm animal uses, other beneficial uses of less than 5,000 gallons per day, use of diffused waters, and impoundment of a stream that originates on one's property "so long as provision is made for . . . continued established minimum flow . . . required to protect the rights of water users below." Permits are specifically required in the case of any increase in daily use by a municipality in excess of 100,000 gallons or three percent, whichever is greater, above its highest per day beneficial use prior to the act; any nonexempt use in excess of 5,000 gallons per day obtained from any source other than a municipal supply; any diversion from a surface source directly into an underground watercourse or basin, unless such diversion was taking place on the effective date of the act and is resulting in no pollution or waste; and any use by an industry from its own water supply within the limits of a municipality in excess of three percent above its highest daily use prior to the act. Any use existing on the date of the act and requiring a permit was permitted to continue while an application for the permit was pending. Improper withdrawal of water which was supposed to be covered by a permit but was not so covered is made a misdemeanor.

Irrigation Limitations--The Iowa commission has strictly limited irrigation use because of its consumptive nature. Thus, while the act authorizes issuance of permits for a maximum initial period of ten years (with the possibility but not the certainty of renewal), the commission has limited permits for irrigation to three years.[26] Similarly, while the statute provides that permits may be issued for such uses as will not interfere with the established average minimum flow of the stream, the commission has issued permits to irrigators only where considerably more than the required minimum flow will still be available to take care of possible growth in municipal and industrial needs. The statute provides that no "vested right" shall be impaired. It also provides that any person operating an irrigation system on the date of the act shall be granted a permit to continue unless by his operation "some other riparian user is damaged." The Iowa commission has ruled that under these provisions one who was irrigating on the effective date of the act does not have a vested right to continue doing so.

Other Conditions--The procedure for obtaining a permit involves an application to the council, followed by a hearing before the water commissioner in which any interested party may take part. An appeal may be taken to the council by any party dissatisfied with the decision of the commissioner. The council's decision may, in turn, be attacked in the courts, in which event the case is tried de novo and the burden is on the council to prove that its order was "reasonable and necessary."

Permits may be granted to nonriparian as well as riparian owners, but nonriparians must themselves obtain some means of access to the water they seek and the commission will issue permits to them only when they show that they have secured such access. Permits may be transferred with the land to which they relate, subject to approval by the council. A permit terminates on nonuse for three years or on a finding by the commissioner that its terms have been breached by the permittee. It may also be suspended in case of emergency.

The Model Act[27]

The model statute drafted by the University of Michigan Legislative Research Center is somewhat difficult to analyze in detail since many of its sections contain alternate provisions or are presented as optional features. In general, it contemplates the creation of a state water resources agency (three alternative provisions being suggested for determining the agency's administrative composition), and issuance of permits for some definite period of time (fifty years being suggested as a possible maximum, although a period of such length would seem to carry with it, in a period of rapid economic development and change, much of the "freeze" effect of prior appropriation). Like the Iowa statute, the Model Act contains provisions for exemption of domestic uses, and for preservation of other existing uses.

Special Features--Several features of the Model Act are of particular interest. It would specifically do away with the acquisition of rights to use water by prescription. It would require a permit for any impoundment of diffused surface water in an amount exceeding a given number of acre-feet, the fixing of such quantity being left to the particular state. It contains an optional provision under which the standard of beneficial use, rather than priority in time of applications, would determine which of two or more competing applicants should receive permits. Under it, each permit would be issued subject to a condition that the use authorized thereunder must not interfere substantially or materially with domestic uses, preserved pre-existing uses, or uses covered by previously issued permits. This condition would be modified under two optional provisions. One of these would make possible a use substantially and materially interfering with domestic, preserved, and previously permitted uses if the new user undertook to replace in kind the water or power lost by reason of the interference. The other would authorize the state water agency to revoke a previously granted permit in favor of a permit to a new user where it found that the new use was more desirable and the new permittee was able and willing to furnish "reasonable compensation" to the old one.

The Model Act contains three alternate sets of provisions relating to appeals from decisions of the water agency to the courts, the principal difference between them being the degree of conclusiveness which would be accorded the agency's findings. All of the alternates would give such findings a more conclusive effect than does the Iowa statute. The Model Act also includes an optional section under which approval by the state water agency would be a prerequisite to the enforcement of any rule, regulation, or order affecting use of water resources by any other state or local agency, and to the exercise by any state or local agency or any person of the power of eminent domain in respect to any right to water resources. It also contains an optional part which would give the state water agency responsibility for administering the state's pollution control laws.

Permit System Advantages and Problems

The permit system has the advantage of striking a measure of balance between prior appropriation and riparian rights. Under it, permit holders obtain some certainty by reason of their permits, while the public is assured of some flexibility in the very fact that the permits are subject to expiration and review. Just how much flexibility and certainty should be provided remains, however, a moot question, as indicated by the striking differences between the length of time for which permits are granted under the Iowa statute and that included (though only as a suggestion) in the Model Act.

Pressures on Agency--The permit system necessarily vests considerable discretion and responsibility in the state agency responsible for administering it. The agency is expected not merely to distribute permits in response to applications as long as water is available--as appropriative rights have been distributed in many parts of the West--but to make the issuance of permits a vehicle for effectuating a long-range water policy in the best interests of the state as a whole. This means that the agency will almost inevitably be subject to conflicting pressures from many directions, probably from its very inception and before it has had much, if any, opportunity to develop basic policies governing its actions in individual cases. For these reasons, the make-up of the state agency is of great importance in the successful administration of a permit system. Some suggestions related to this point are outlined in the section below.

Administration Problems--The permit system does not of itself solve the problem of enforcement of limitations on rights of use, which may prove inherently more difficult in some respects in the East than it has so far proved in the West. This seems particularly likely in connection with irrigation. In the West, where irrigation water is distributed by canal, water masters can control the water supplied to a user by controlling headgates. In the East, where sprinkler-type irrigation is normally used, it is not a simple matter to insure that a farmer with a pipe extending into a stream will operate his pump only at such times and for as long a time as may be authorized by his permit. The Iowa experience to date indicates that this problem may be successfully met by reliance on cooperation and local self-policing, supplemented by an extensive system of stream gages. The caution exercised by the Iowa water agency in limiting irrigation permits to three years and in insisting that flows considerably above existing minimums be preserved to accomodate future growth of other uses has no doubt also contributed to keeping this problem within soluble limits.

A POSSIBLE GRADUAL APPROACH TO ADJUSTMENT OF WATER RIGHTS LAW

Because of the importance of water rights legislation to the economy of a state, as well as to private individuals within the state, it is important that any changes in legislation be fully considered. There would also seem to be an advantage in creating a state water agency and giving it the opportunity to build up both an adequate staff and a body of facts and experience relating to the water resources, problems, and opportunities of the state before it is faced with the task of actually administering and enforcing a new system. This was what occurred in Iowa, where a resources council was created in 1951 (in succession to an earlier group), and where a permit system was instituted six years later.

Valley Conditions Favor Gradual Approach--The Tennessee Valley states are fortunate in possessing water resources more ample generally in relation to their foreseeable needs than those of most others. As indicated earlier in this report, there is no present widespread crisis in this area nor any likelihood that one may soon develop. These states are thus in a position to employ a gradual approach to the problem if they so desire, and in so doing to take advantage not only of their own experience as it develops but also of that of other states which may be compelled to move further and faster.

Possible Early Adjustments--At the same time, certain legal changes could be made at once to take care of presently apparent problems. One of these, as already indicated, would involve immediate creation and staffing of a water agency to begin active work in the field. In some states, this agency might assume responsibility for activities related to water resources which are now divided among other agencies. If there is no such assumption of responsibility, the statute setting up the new agency should provide for close coordination.

A second step might well be to clarify the position of municipalities in regard to water use. Since such use is not only essential but is or can be largely non-consumptive, it may be desirable to make municipal water supply equivalent to a recognized riparian use (in any state where it does not already clearly have that status) and sanction generally withdrawals of water for that purpose, subject to four conditions for the protection of other users. These are (1) that water withdrawn be returned as fully as possible to the source from which it is taken, and as close as economically feasible to the point of withdrawal; (2) that before being returned, it be adequately treated to the extent necessary to protect downstream users; (3) that, where the source is a relatively small stream, appropriate provision be made for storage during periods of high streamflow so as to reduce potential drains on the water resource during low-flow periods; and (4) that arrangements be made to compensate owners of land between points of withdrawal and return who can show actual present or future damage occurring from the diminution in the flow of the stream past their properties as a result of the diversion. Such conditions would seem generally adequate to protect other users, while at the same time municipalities would be put in a position to obtain water on a basis involving less resort to expensive eminent domain proceedings. A third step might be to attach similar conditions to industrial use, which involves problems basically similar to those of municipal use. If such conditions were required and enforced by the new water agency (and other administrative units having jurisdiction), much would be accomplished towards assuring both adequate municipal and industrial water supplies, and municipal and industrial use on a basis which would maximize available supply for the benefit of other users.

A principal remaining problem would be to assure that water was made available for consumptive uses such as irrigation so far as feasible but not to such an extent as to injure (at least in the absence of special circumstances) other and non-consumptive uses and users. Data referred to earlier in this study indicates that potential irrigation use may present a real problem only in limited areas of the Tennessee Valley. A new state water agency might be able to recommend a number of approaches to the problem, adapted to the specific needs of the particular state and of different drainage areas within the state. Such approaches, depending on the facts, might involve permits, storage, formation of irrigation districts, and other measures in various combinations. Conceivably, such a gradual approach might point ultimately to adoption of a permit system applicable only to certain types of uses and in certain limited areas within the state. Simplification in this connection would have obvious advantages in relation to the difficulties and expense of administration.

It is not to be expected that a law will be placed upon the statute books of any state that will automatically solve its water problems. The West has struggled with its water problems for years without evolving any perfect solution for them. In the Eastern states, too, a process of developing administrative experience and legislative change over a long period seems in prospect. In such circumstances, a step-by-step approach to the problem would seem to have much to recommend it.

A REGIONAL APPROACH TO ADMINISTRATION

Regardless of the system of water rights legislation under which a state may elect to operate, there will be certain problems and opportunities in the formation of the administrative framework. The Model Act drafted at the University of Michigan indicates the importance of these problems by offering several alternatives in the make-up of the administrative agency. It goes without saying that the members appointed to such an agency should have among them the training and experience necessary to pass on the many problems in the water resource field. In addition, it seems necessary that they represent adequately the various water uses in the state and, equally important, the various regions of the state if these regions have divergent characteristics.

Many states are naturally subdivided by topographic, hydrologic, economic, and political factors into two or more regions which have distinctive characteristics as to both water supply and possible future uses. A particularly interesting example is the State of Tennessee which can logically be subdivided into four distinct regions. The first of these regions would include the Tennessee River Basin upstream from Chattanooga; the second the Tennessee River Basin downstream from Chattanooga; the third the Cumberland River Basin; and the fourth the Mississippi River drainage in western Tennessee. Anyone familiar with the geography and economics of the state will readily appreciate the differences among these four regions with respect to physical characteristics, water supply, the nature and extent of present water resource development, the opportunities for future development, and the potential for various water uses.

It might be difficult for a 5- or 7-man central council, even if appointed from over the state, to weigh, without prejudice for any region or use, the irrigation problems of a small tobacco farmer in eastern Tennessee and those of a large cotton planter in western Tennessee, or of a boat dock owner on Watauga Lake in the mountains and one on Kentucky Lake in the flat western region. Under these circumstances it would seem more practical for any system of water rights legislation to be administered by separate regional commissions appointed by the governor to represent the major uses of their respective regions. These regional groups would operate under the over-all control and within the policies established by a central commission.

The central body might consist of the four regional chairmen together with one or more members appointed from the state at large. The professional engineering and legal staff would be attached to the central body. The central agency would act in all matters involving state policy as a whole.

One of the functions of the regional bodies might be to handle, at the working level, the important State-Federal water resource relationships. In Tennessee, the major Federal water resource agency in the two halves of the Tennessee River Basin is the TVA, but in the Cumberland and Mississippi River portions the Corps of Engineers is the principal agency. With administration by regional bodies this relationship could be more clear cut and mutually productive.

It would appear that a regional setup such as the one described above would offer distinct advantages in satisfying the desires and needs of each region of the state with the least amount of state-wide conflict. The regional councils would fit in very well with the limited-area concept of water legislation application which has been advocated in some of the Eastern states.

FOOTNOTES

(Footnotes to Chapter 6 will be included in the final draft of this report.)